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THE CONICAL SCANNER EVALUATION SYSTEM DESIGN

Prepared for:

GODDARD SPACE FLIGHT CENTER

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ABSTRACT

This document presents the software design for the Conical Scanner Evaluation System. The purpose of this system is to support the performance analysis of the Landsat-D Conical Scanners, which are infrared horizon detection attitude sensors designed for improved accuracy. The system consists of six functionally independent subsystems and five interface data bases. This document describes the system structure and interfaces of each of the subsystems. The content, format, and file structure of each of the data bases is specified. For each subsystem, the functional logic, the control parameters, the baseline structure, and each of the subroutines are described. The subroutine descriptions include a procedure definition and the input and output parameters.

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SECTION 1 - SYSTEM OVERIVEW

1.1 INTRODUCTION

The Landsat-D spacecraft, which is scheduled for launch in July 1982, will carry two Conical Scanners. These scanners will provide Earth direction determination data throughout the mission and attitude determination and control data during the initial phase of the flight. The attitude data obtained by the conical scanners will be used to control the spacecraft to a near nominal zero pitch-roll-yaw attitude. The conical scanners will provide data for the backup attitude determination and control system in case of failure of the primary system. The primary system will use two NASA star trackers and gyroscope data. The Onboard Computer (OBC) will use data from these sensors to compute attitudes which are expected to be accurate to a hundredth of a degree.

The Conical Scanner is manufactured by Ithaco, Inc. The design of the Conical Scanner is intended to provide improved accuracy over previous Ithaco horizon scanner designs. The Landsat-D mission provides an excellent opportunity to assess its inflight performance because of the availability of sensor measurements from both conical scanners as well as the more accurate attitude data from the OBC. An important part of the plan for evaluating the conical scanner involves studying the actual sensor measurements with respect to measurements predicted from the OBC attitudes using comprehensive models of the conical scanner and the Earth. The residual errors between the actual and predicted measurements will be analyzed to identify sensor biases. Adjustments in model parameters to account for these biases will lead to the inflight calibration of the conical scanners. The residual errors remaining after inflight calibration will provide data on the level of accuracy obtainable from these sensors.

The purpose of this document is to provide a detailed design of the software system that will support the performance analysis of the Landsat-D conical scanner. Section 1 gives an overview of the system and its major subsystems and data bases. Section 2 defines the structure and contents of each data base in the system. Sections 3 through 8 provide detailed specifications of the major subsystems, including baseline diagrams, subroutine descriptions, and input/output requirements.

1.2 SYSTEM PURPOSE

The Conical Scanner Evaluation System (CSES) is a software package that will serve as an essential tool in the performance evaluation of the Ithaco Conical Scanners onboard Landsat-D. A detailed description of the overall evaluation plan is available in Reference 1. The main role of the CSES in the evaluation process is summarized in the following steps:

(1) Extract conical scanner data, OBC attitudes, and ephemeris from the spacecraft telemetry. Store the extracted data in a data library for later use.

(2) Extract Earth infrared horizon radiance profiles from the Horizon Radiance Data Base. Integrate the radiances over the spectral bandpass of the conical scanner to obtain radiance profiles for the Landsat-D conical scanner performance analysis.

(3) Model the responses of the conical scanner sensor optics and electronics to seasonal and systematic variations in the Earth horizon radiance.

(4) Predict conical scanner measurements using reference attitudes (normally these attitudes are from the OBC). Store the predicted measurements along with the corresponding observed measurements in a data library for later analysis.

(5) Generate plots of the observed and predicted measurements for qualitative comparison and review.

(6) Generate statistics on the observed and predicted measurements and the computed residuals.

1.3 BASIC STRUCTURE

The CSES is made up of the following subsystems and data basos, each of which supports a portion of the above activities:

Subsystems

1. Telemetry Processor
2. Spectral Bandpass Intogrator
3. Sensor Optics and Electronics Simulator
4. Scanner Measurement Predictor
5. Data Plotting and Fitting Utility
6. Scan Path Plotter

Data Bases

1. Telemetry [illegible]a Base
2. Horizon [illegible]nce Data Base
3. Landsat-D Radiance Data Base
4. Triggering Heights Data Base
5. Measurements Data Base

Figure 1-1 diagrams the basic connections between the subsystems and data bases. The following section gives a brief description of each subsystem.

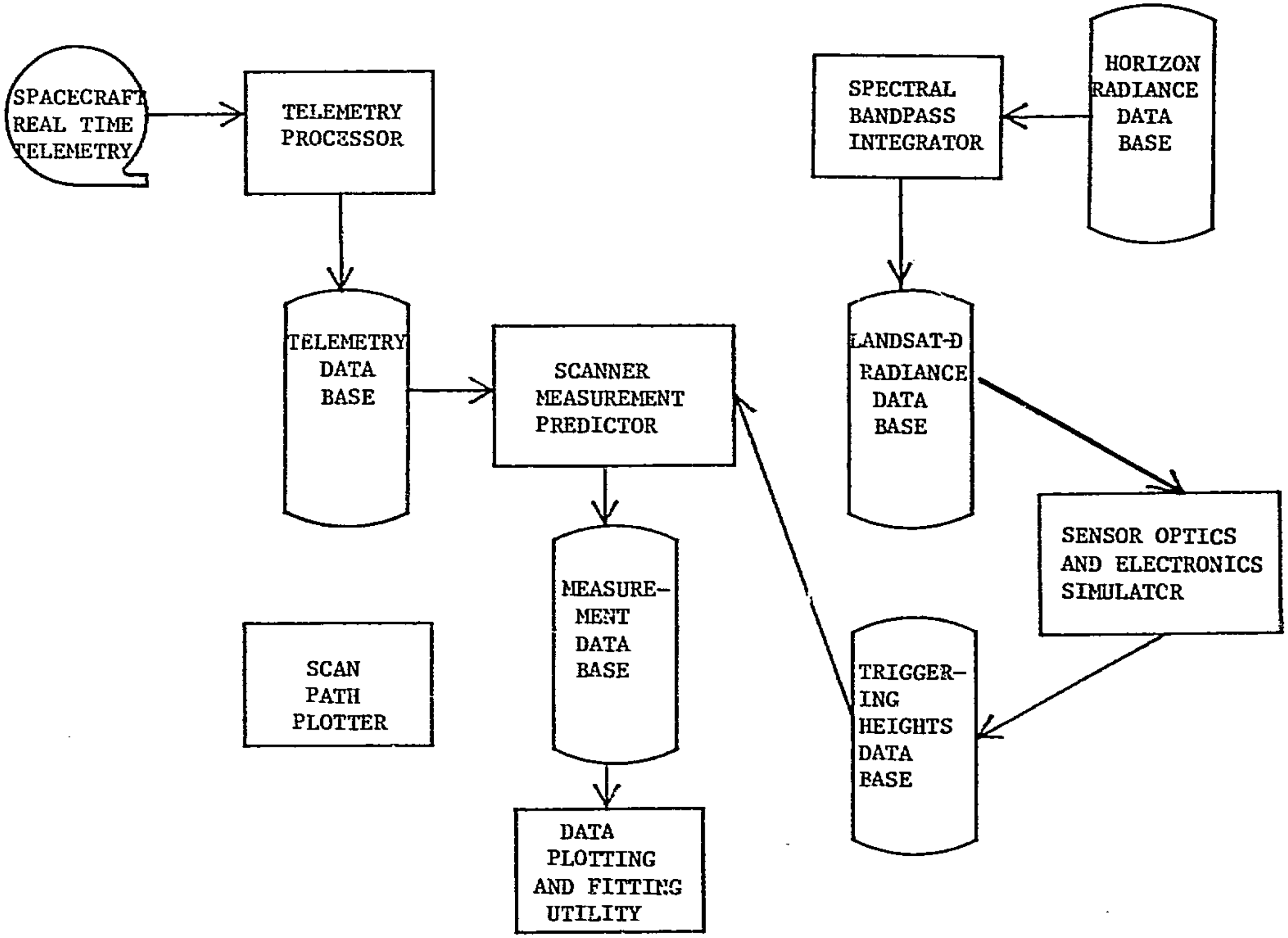

Figure 1-1 Relationships Between Subsystems and Data Bases

1.4 MAJOR SUBSYSTEMS

1.4.1 Telemetry Processor

The spacecraft telemetry stream contains a large volume of science and engineering data of which only a small subset is needed for the conical scanner performance evaluation. The Telemetry Processor extracts this subset, which includes conical scanner sensor measurements, OBC attitudes, ephemeris, and timing information, from the spacecraft telemetry and stores it in the Telemetry Data Base. The data can be retrieved from the data base for use in other phases of the evaluation process. The Telemetry Processor performs all necessary data conversion and validation before entering the data in the Telemetry Data Base.

1.4.2 Spectral Bandpass Integrator

The Spectral Bandpass Integrator extracts Earth horizon radiance profiles from an existing data base called the Horizon Radiance Data Base (HRDB), and processes them so that they are suitable for use in the Landsat-D conical scanner analysis. The HRDB contains radiance profiles for all latitude bands and seasons. The radiances in these profiles range over a set of small spectral intervals from about 8 to 22 microns. The Spectral Bandpass Integrator integrates radiances in the selected profiles over the specific spectral bandpass of the conical scanner. These processed radiance profiles are stored in the Landsat-D Radiance Data Base. They are retrieved from this data base as needed for input to the Sensor Optics and Electronics Simulator.

1.4.3 Sensor Optics and Electronics Simulator

The main function of the Sensor Optics and Electronics Simulator is to predict the conical scanner sensor responses to seasonal, systematic variations in the Earth horizon radiance. The predicted responses are stored in the Triggering Heights Data Base in the form of horizon triggering heights for all scanner horizon crossing positions and seasons. The data are retrieved from the data base as needed for input to the Scanner Measurement Predictor. In addition, analyses of the data can be performed to study the sensitivity of the scanner to various parameters.

1.4.4 Scanner Measurement Predictor

The primary functions of the Scanner Measurement Predictor are to predict conical scanner measurements and generate a dataset in the Measurements Data Base containing the predicted measurements. The Scanner Measurement Predictor uses comprehensive models of the conical scanner and the Earth which include adjustable parameters that simulate all significant error sources for the scanner measurements. The following list summarizes the modeled error sources:

(1) Sensor mounting alignment and scan cone angle variations
(2) Horizon triggering height variations and Earth angular radius biases
(3) Constant measurement biases
(4) Output voltage conversions to telemetry counts
(5) Earth oblateness effects
(6) Systematic horizon radiance effects
(7) Temperature dependence

Selectively adjusting these parameters on successive runs of the Scanner Measurement Predictor leads to the inflight calibration of the Landsat-D conical scanners.

The central purpose of the Scanner Measurement Predictor is to provide a useful, effective tool for the performance evaluation of the Landsat-D conical scanners. To meet this goal, its design includes several input/output options. For example, while the attitude data needed in the model are normally the OBC attitudes from the telemetry data base, there is an option to input attitude data in the form of constant pitch, roll, and yaw. Another option is to generate a dataset containing predicted measurements for one set of model parameters along with predicted measurements from a different set of model parameters (instead of the usual predicted vs. observed dataset). The purpose of this feature is to readily provide theoretical estimates of the effects produced by variations in model parameters. These features and others are described in detail in Section 6.

1.4.5 Data Plotting and Fitting Utility

The Data Plotting and Fitting Utility (DPFU) produces Calcomp plots of selected data from the Measurements Data Base. The utility is designed so that any variable can be selected from a chosen dataset to be plotted against any other variable from the dataset. The DPFU provides the following options:

- Overlaying or stacking a series of plots
- Labeling axes and specifying plot titles
- Setting scales
- Performing a polynomial fit of the selected data
- Performing a finite Fourier series fit of the data

The DPFU computes the mean of each variable and displays it on the plot. Typical plots include:

- o Predicted or observed measurements vs. time
- o Residual errors (difference between observed and predicted) vs. time
- o Various orbit and attitude parameters vs. time
- o Correlation plots of selected variables

1.4.6 Scan Path Plotter

The Scan Path Plotter plots the path of the scanner field-of-view across the Earth's surface. The scan path plot helps to provide a general understanding of the scan geometry and is particularly useful for showing the scan path on the Earth when the scanner measurements are affected by the presence of cold clouds. The plots can be overlaid on GOES Earth photographs to show the scan geometry in relation to meteorological conditions.

A Scan Path Plotter was developed and used in the Seasat and Magsat missions. The Landsat-D Scan Path Plotter is based on this existing utility but will be modified to accept spacecraft attitude and orbit parameters in a format convenient for the Landsat-D analysis. Also, the utility will be improved to model the Earth oblateness in the scan path computation.

SECTION 2 · DATA BASE DESCRIPTIONS

2.1 TELEMETRY DATA BASE (TDB)

2.1.1 Variables and Formats

The Telemetry Data Base contains the set of variables described in Table 2-1.

2.1.2 File Structure

Each dataset in the Telemetry Data Base has the following file characteristics:

(1) File organization: sequential
(2) Blocksize: 3778 bytes
(3) Record format: Fixed-length
(4) Record length: 3778 bytes
(5) Record structure: Table 2-2 gives a byte description of each record in the Telemetry Data Base.

Table 2-1 Telemetry Data Base Variables

Variable Name	Description	Type	Units
IROLLF(2)	Fine Roll Error	I*2	Counts
IROLLC(2)	Coarse Roll Error	I*2	Counts
IPITF(2)	Fine Pitch Error	I*2	Counts
IPITC(2)	Coarse Pitch Error	I*2	Counts
ISIGNL(2)	Signal Status	I*2	Counts
TIME	GMT Reading at start of each frame in second since Sept. 1, 1957	R*8	Sec
ITEMP(2)	Scanner Temperature	I*2	Counts
IBOLO(2)	Bolometer Temperature	I*2	Counts
ISENSR(2)	Sensor Status	I*2	Counts
EPARMS(2)	Euler Parameters - OBC Reference Attitudes	R*4	N/A
MODES(5)	Mode flags indicating operational status of the spacecraft	I*2	Counts
EPHPOS(3)	ECI Axis components of spacecraft position	R*4	km
EPHVEL(3)	ECI components of spacecraft velocity	R*4	km/sec

Table 2-2 Telemetry Data Base Record Structure

Byte Displacement	Contents
0-1023	TIME (1) - TIME (128)
1024-1027	ITEMP(1)-ITEMP(2)
1028-1031	IBOLO(1)-IBOLO(2)
1032-1041	MODES(1)-MODES(5)
1042-1297	IROLLF(1,1)-IROLLF(128,1)
1298-1553	IROLLF(1,2)-IROLLF(128,2)
1554-1809	IROLLC(1,1)-IROLLC(128,1)
1810-2065	IROLLC(1,2)-IROLLC(128,2)
2066-2321	IPITF(1,1)-IPITF(128,1)
2322-2577	IPITF(1,2)-IPITF(128,2)
2578-2833	IPITC(1,1)-IPITC(128,1)
2834-3089	IPITC(1,2)-IPITC(128,2)
3090-3345	ISIGNL(1,1)-ISIGNL(128,1)
3346-3601	ISIGNL(1,2)-ISIGNL(128,2)
3602-3609	ISENSR(1,1)-ISENSR(4,1)
3610-3617	ISENSR(1,2)-ISENSR(4,2)
3618-3681	EPARMS(1,1)-EPARMS(4,4)
3682-3729	EPHPOS(1,1)-EPHPOS(3,4)
3730-3777	EPHVEL(1,1)-EPHVEL(3,4)

2.2 HORIZON RADIANCE DATA BASE (HRDB)

The Horizon Radiance Data Base HRDB contains Earth radiance data for a range of small spectral intervals around 15 microns for various latitudes, times of year, and Earth viewing angles. The HRDB is described in Reference 2.

2.2.1 Variables and Formats

The HRDB contains the variables described in Table 2-3.

2.2.2 File Structure

The HRDB has the following characteristics

1. File organization: Direct Access
2. Blocksize: 7244
3. Record format: Blocked fixed-length
4. Record length: 7244
5. Number of tracks: 217
6. Number of records: 217
   record 1 header record
   records 2 to 217 - data records
7. Record structure:
   a. The structure for the header record is shown in Table 2-4
   b. The structure for the data records is shown in Table 2-5

The data for a particular latitude and time of year spans two records on the dataset. The starting record number for a particular latitude and time of year (EL_i, T_j) is determined from the following equation:

$$\text{Record number} = 2 * [(j - 1) * NL + i] \qquad (2\text{-}1)$$

Table 2-3 HRDB Variables

Variable Name	Description*	Type	Units
NF	Number of wavelengths (71)	I*4	
NH	Number of tangent height values (41)	I*4	
NZ	Number of zenith angles values(10)	I*4	
NL	Number of latitudes (9)	I*4	
NT	Number of time values (12)	I*4	
W(i) (i=1,NF)	Wavelength	R*4	microns
H(i) (i=1,NH)	Tangent height	R*4	km
Z(i) (i=1,NZ)	Zenith angle	R*4	degrees
EL(i) (i=1,NL)	Latitude	R*4	degrees
T(i) (i=1,NT)	Time of the year	L*4	
R(i,k) (i=1,NF k=1,NH+NZ)	Radiance	R*4	$\frac{\text{watt}}{\text{cm}^2\text{.SR.}}$

* The values given in parentheses are the default values.

Table 2-4 HRDB Header Record Structure

Byte Displacement	Name	Description*
0	NF	Number of wavelengths (71)
4	NH	Number of tangent height values (41)
8	NZ	Number of zenith angle values (10)
12	NL	Number of latitudes (9)
16	NT	Number of time values (12)
20	W_1	First wavelength in microns (8.0)
24	W_2	Second wavelength (8.2)
	.	
	.	
	.	
304	W_{NF}	NF-th wavelength (22.0)
308	H_1	First tangent height in Km (0.0)
312	H_2	Second tangent height in Km (2.0)
	.	
	.	
	.	
472	H_{NH}	NH-th tangent height in Km (80.0)
476	Z_1	First zenith angle in degrees (90.0)
480	Z_2	Second zenith angle in degrees (100.0)
	.	
	.	
	.	
516	Z_{NZ}	NZ-th zenith angle in degrees (180.0)
520	EL_1	First latitude (80.0)
	.	
	.	
	.	
556	EL_{NL}	NL-th latitude (-80.0)+
560	T_1	First value of time (JAN.)
	.	
	.	
	.	
608	T_{NT}	NT-th value of time (DEC.)

* Values given in parenthese are the default values.

\+ Negative value implies south latitude

Table 2-5 HRDB Data Record Structure

Note: Two consecutive records contain data for a particular latitude and time of year.

Byte Displacement	Name	Description
0	R(1,1)	Radiance for (W_1,H_1)
4	R(2,1)	Radiance for (W_2,H_1)
8	R(3,1)	Radiance for (W_3,H_1)
.	.	
.	.	
280	R(NF,1)	Radiance for (W_{NF},H_1)
284	R(1,2)	Radiance for (W_1,H_2)
.	.	
.	.	
.	.	
7240	R(26,36)	Radiance for (W_{26},H_{36})

<u>End of the first record</u>

<u>Beginning of the second record</u>

7244	R(26,37)	Radiance for (W_{26},H_{37})
.	.	
.	.	
.	.	
7424	R(NF,NH)	Radiance for (W_{NF},H_{NH})
7428	R(1,NH+1)	Radiance for (W_1,Z_1)
.	.	
.	.	
.	.	
14480	R(NF,NH+NZ)	Radiance for (W_{NF},Z_{NZ})

2.3 LANDSAT-D RADIANCE DATA BASE (LRDB)

2.3.1 Variables and Formats

The LRDB contains the variables shown in Table 2-6.

2.3.2 File Structure

The data base will consist of an unformatted direct access file with following file characteristics.

1. File organization: Direct Access
2. Blocksize: 204 bytes
3. Record format: Fixed-length
4. Record length: 204 bytes
5. Number of tracks: 4
6. Number of records: 110
7. Record structure: There are two file header records with the contents shown in Table 2-7.

The data record number for a particular latitude and time of the year (EL_i, T_j) is determined from the following equation

$$\text{Record number} = (j - 1)*NL+i+2 \qquad (2\text{-}2)$$

The data record format is shown in Table 2-8.

Table 2-6 LRDB Variables

Name	Description	Type	Unit
NH	Number of tangent heights values	I*4	
NZ	Number of the zenith angles	I*4	
NT	Number of times of the year	I*4	
NL	Number of latitudes	I*4	
H(i) i=1,NH	Tangent heights	R*4	km
Z(i) i=1,NZ	Zenith angles	R*4	degrees
EL(i) i=1,NL	Latitudes	R*4	degrees
T(i) i=1,NT	Times of the year	I*4	months
RAD(i) i=1,(NH+NZ)	Radiance Profile	R*4	$\frac{\text{watt}}{\text{cm}^2\text{.SR}}$

Table 2-7 LRDB Header Records

Header Record 1

Byte Displacement	Variable
0	NH
4	NZ
8	NL
12	NT
16	EL(i), i=1, NL
16+4*NL	T(i), i=1, NT

Header Record 2

Byte Displacement	Variable
0	H(i), i=1, NH
4*NH	Z(i),i=1,NZ

Table 2-8 LRDB Data Record

Byte Displacement	Variable	Description
0	RAD(1)	Radiance for H(1)
4	RAD(2)	Radiance for H(2)
.	.	
.	.	
.	.	
4*NH-4	RAD(NH)	Radiance for H(NH)
4*NH	RAD(NH+1)	Radiance for zenith angle Z(1)
4*NH+4	RAD(NH+2)	Radiance for zenith angle Z(2)
.	.	
.	.	
.	.	
4*NH+NZ-4	RAD(NH+NZ)	Radiance for zenith angle Z(NZ)

2.4 TRIGGERING HEIGHTS DATA BASE (THDB)

2.4.1 Variables and Formats

The Triggering Heights Data Base (THDB) contains just one variable, T of type R*4, which provides the horizon triggering heights in kilometers.

2.4.2 File Structure

The THDB has the following file characteristics:

File organization:	Direct Access
Blocksize:	2896 bytes
Record format:	Fixed-length
Record Length:	2896 bytes
Number of records:	12
Number of tracks:	6
Record Structure:	The structure of each record is shown in Table 2-9.

Each record will provide the triggering height data for one month. The record number will correspond to the month number for which data is provided.

Table 2-9 THDB Record Structure

Byte Displacement	Name	Description
0	T(i,j,k)	Triggering heights, where i=1,181 indicates the satellite orbit position as degrees of true anomoly from the ascending node over the range 0 to 360 with increments of 2 degrees. j = 1,2 indicates the horizon crossing, 1 for Earth-in and 2 for Earth-out. k = 1,2 indicates the scanner number.

2.5 MEASUREMENTS DATA BASE

2.5.1 Variables and Formats

The Measurements Data Base contains the set of variables described in Table 2-10.

2.5.2 File Structure

Each dataset in the Measurements Data Base has the following file characteristics:

(1) File organization: Sequential
(2) Block size: 7236
(3) Record type: Blocked Fixed length
(4) Record length: 108 bytes
(5) Record structure: Table 2-11 gives a byte description of the record structure.

Table 2-10 Measurements Data Base Variables

Variable Name	Description	Type	Units
TIME	Time associated with each measurement in seconds since Sept. 1, 1957.	R*8	Sec
WIDTH(2)	Observed Earth width angle	R*4	Deg
PHASE(2)	Observed Earth phase angle	R*4	Deg
WIDTHP(2)	Predicted Earth width angle	R*4	Deg
PHASEP(2)	Predicted Earth phase angle	R*4	Deg
BOLO(2)	Bolometer temperature	R*4	^{o}C
TEMP(2)	Scanner temperature	R*4	^{o}C
ISIGNL(2)	Signal Status	I*2	
ISENSR(2)	Sensor Status	I*2	
EILAT(2)	Predicted Earth-in horizon crossing latitude	R*4	Deg
EOLAT(2)	Predicted Earth-out horizon crossing latitude	R*4	Deg
PITCH	Reference attitude pitch measurement	R*4	Deg
ROLL	Reference attitude roll measurement	R*4	Deg
YAW	Reference attitude yaw measurement	R*4	Deg
ALT	Spacecraft altitude	R*4	km
SUBLAT	Subsatellite latitude	R*4	Deg
SUBLON	Subsatellite longitude	R*4	Deg
ORBPHA	Subsatellite orbit phase angle relative to the ascending node	R*4	Deg

NOTE: There are two values associated with each variable that is dimensioned size 2, one for each scanner.

Table 2-11 Measurements Data Base Record Structure

Byte Displacement	Content
0-7	TIME
8-15	WIDTH(1),WIDTH(2)
16-23	PHASE(1),PHASE(2)
24-31	WIDTHP(1),WIDTHP(2)
32-39	PHASEP(1),PHASEP(2)
40-47	BOLO(1),BOLO(2)
48-55	TEMP(1),TEMP(2)
56-59	ISIGNL(1),ISIGNL(2)
60-63	ISENSR(1),ISENSR(2)
64-71	EILAT(1),EILAT(2)
72-79	EOLAT(1),EOLAT(2)
80-83	PITCH
84-87	ROLL
88-91	YAW
92-95	ALT
96-99	SUBLAT
100-103	SUBLON
104-107	ORBPHA

SECTION 3 - TELEMETRY PROCESSOR

3.1 FUNCTIONAL DESCRIPTION

The Telemetry Processor (TP) extracts attitude, ephemeris, timing, and conical scanner data from the spacecraft telemetry. Table 3-1 provides a complete specification of these data by variable name, description, sample rate, telemetry ID, and location in the telemetry stream. Note that the spacecraft telemetry is structured such that a minor frame contains 128 8-bit words and a major frame contains 128 minor frames. See Reference 3 for further information about the structure and content of the Realtime Spacecraft Telemetry (Mission and Engineering Formats).

Two important functions of the TP are to attach time tags to the extracted data and to detect any anomalies in the timing information (e.g., unexpected gaps or backtracking). The Digital Processing Unit (DPU) time data (entry 15 in Table 3-1) are referenced to the major frame synchronization pulse that signals the beginning of each major frame. The TP uses this initial timing information together with the data rate and frame counter to time tag each row of the telemetry array. Specifically, at the 8K-bps data rate, each increment of the frame counter represents 0.125 seconds. At the 1K-bps data rate, each increment represents 1 second. The TP uses the GMT status and update reports from the OBC (entry 25 in Table 3-1) as an additional timing and synchronization check.

Before entering the extracted data in the Telemetry database, the TP performs all necessary data conversions and validations. The validation procedure checks that each data element is within an acceptable range. If a value is not within its given range, the value is replaced with the missing value indicator.

Table 3-1 Conical Scanner Evaluation System Telemetry Extract (1 of 2)

VARIABLE NAME	DESCRIPTION	TELE-METRY USER ID	SAMPLE RATE	MINOR FRAME WORD NUMBER	MINOR FRAME NUMBER (SUBCOMS)
IQUAL	Quality flag: 0 = good minor frame FF = bad minor frame	C/DH	128	0	
IRATE	Data rate (1 Kbps or 8 Kbps)	C/DH	128	3	
IFMT	Format ID (Mission or engineering)	C/DH	128	3	
NFRAME	Frame counter	C/DH	128	65	
IROLLF(1)	ESA-1 Fine Roll Error	ESAM	128	72	
IROLLF(2)	ESA-2 Fine Roll Error	ESAM	128	73	
ISIGNL(1)	ESA-1 Signal Status	ESAM	128	38	
ISIGNL(2)	ESA-2 Signal Status	ESAM	128	102	
IROLLC(1)	ESA-1 Coarse Roll Error	ESAM	128	104	
IROLLC(2)	ESA-2 Coarse Roll Error	ESAM	128	105	
IPITF(1)	ESA-1 Fine Pitch Error	ESAM	128	8	
IPITF(2)	ESA-2 Fine Pitch Error	ESAM	128	9	
IPITC(1)	ESA-1 Coarse Pitch Error	ESAM	128	40	
IPITC(2)	ESA-2 Coarse Pitch Error	ESAM	128	41	
DPUTIM(6)	DPU Time Code Data: Spacecraft ID, Day, Hour, Min,sec, Msec	DPU	1	32	0-6
ITEMP(1)	ESA-1 Temperature	ESAM	1	33	44
ITEMP(2)	ESA-2 Temperature	ESAM	1	33	46
IBOLO(1)	ESA-1 Bolometer Temperature	ESAM	1	33	47
IBOLO(2)	ESA-2 Bolometer Temperature	ESAM	1	33	48
ISENSR(1)	ESA-1 Sensor Status	ESAM	4	99	6,38,70,102
ISENSR(2)	ESA-2 Sensor Status	ESAM	4	99	22,54,86,118

Table 3-1 Conical Scanner Evaluation System Telemetry Extract (2 Of 2)

VARIABLE NAME	DESCRIPTION	TELE-METRY USER ID	SAMPLE RATE	MINOR FRAME WORD NUMBER	MINOR FRAME NUMBER (SUBCOMS)
EPARMS(4)	Euler Parameters that specify vehicle orientation relative to ECI frame	OBC	4	115-126	9,41,73,105
MODES(4)	Mode flags indicating stellar acquisition status, earth-pointing status, ephemeris source, sun presence	OBC	1	91, 95,118 122	23
EPHPOS(3)	ECI axis components of FS position vector	OBC	4	91-95,108-114	17,49,81,113
EPHVEL(3)	ECI axis components of FS velocity vector	OBC	4	115-126	17,49,81,113
FSTIME	Flight software time	OBC	4	91-95	30,62,94,126
GMTUPD(3)	GMT update report	OBC	1	91-95, 108-113	97

The TP generates a report of the characteristics of the output dataset, including information about time span covered, the data rate, gaps in the telemetry stream, clusters of bad minor frames, mode changes, the total number of bad minor frames, and the total number of major frames in the dataset.

3.2 INPUTS AND OUTPUTS

3.2.1 NAMELIST Inputs

The following program control parameters are input through the NAMELIST input file, &TPIN:

IFIRST	The number of the first record in the Telemetry file to be read.
LAST	The number of the last record in the Telemetry file to be read. If LAST=0, the entire file will be read.
IHEX	If IHEX=1, each record of the Telemetry file that contains the OBC reference attitudes is written in the debug output file in hexadecimal format. If IHEX=2, every record of the Telemetry file is written in the debug file in hexadecimal format. If IHEX=0, no debug output is generated.
ITLM	The logical unit number of the Telemetry file.
MAXBAD	The maximum number of bad records per major frame that are allowed before a diagnostic message is issued.
IDBG	The logical unit number of the Debug output file.

3.2.2 Dataset Inputs

The input to the Telemetry processor is a Landsat-D Telemetry tape which contains the Landsat-D Realtime Spacecraft Telemetry in mission and/or engineering formats. The data format of this tape is defined in Reference 3.

3.2.3 Dataset Outputs

The telemetry processor writes to the Telemetry Data Base. See Section 2.1 for a description of the format and content of entries in the Telemetry Data Base.

3.2.4 Printouts

The telemetry processor generates the following printouts.

Summary Report

The summary of the data span processing contains the following:

- NAMELIST Parameters
- Initial and Final GMT reading
- Initial Data Rate
- Gaps in data and changes in data rate (listed by major frame number, minor frame number, last GMT reading, current GMT reading, current data rate)
- Clusters (i.e., more than MAXBAD per major frame) of records that have been flagged as bad (listed by major frame number and minor frame numbers of bad records).
- Total number of major frames in output dataset
- Total number of bad records
- Mode flags and indication of any changes in the mode flags

Debug Output File (Optional)

Contains selected telemetry records of the input and output datasets written in hexadecimal format and selected internal variables. The amount of debug output is controlled by NAMELIST parameters.

3.3 SYSTEM STRUCTURE

Figure 3-1 contains the baseline diagram of the Telemetry Processor. The routine TPMAIN serves as the driver of the system. It initializes all necessary parameters, performs all input and output, and calls UNPACK, TIMTAG, and CHECK to parse the telemetry stream, perform time-tagging, check for gaps in the telemetry, and flag missing or out-of-range values. Figure 3-2 provides a flow diagram of the system.

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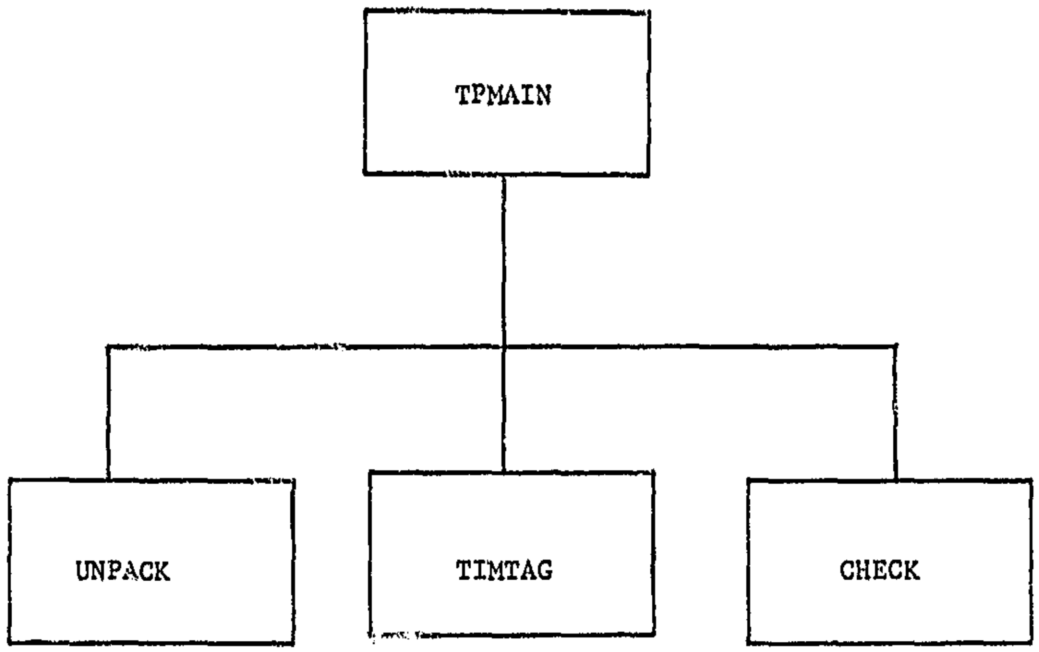

Figure 3-1 Telemetry Processor Baseline Diagram

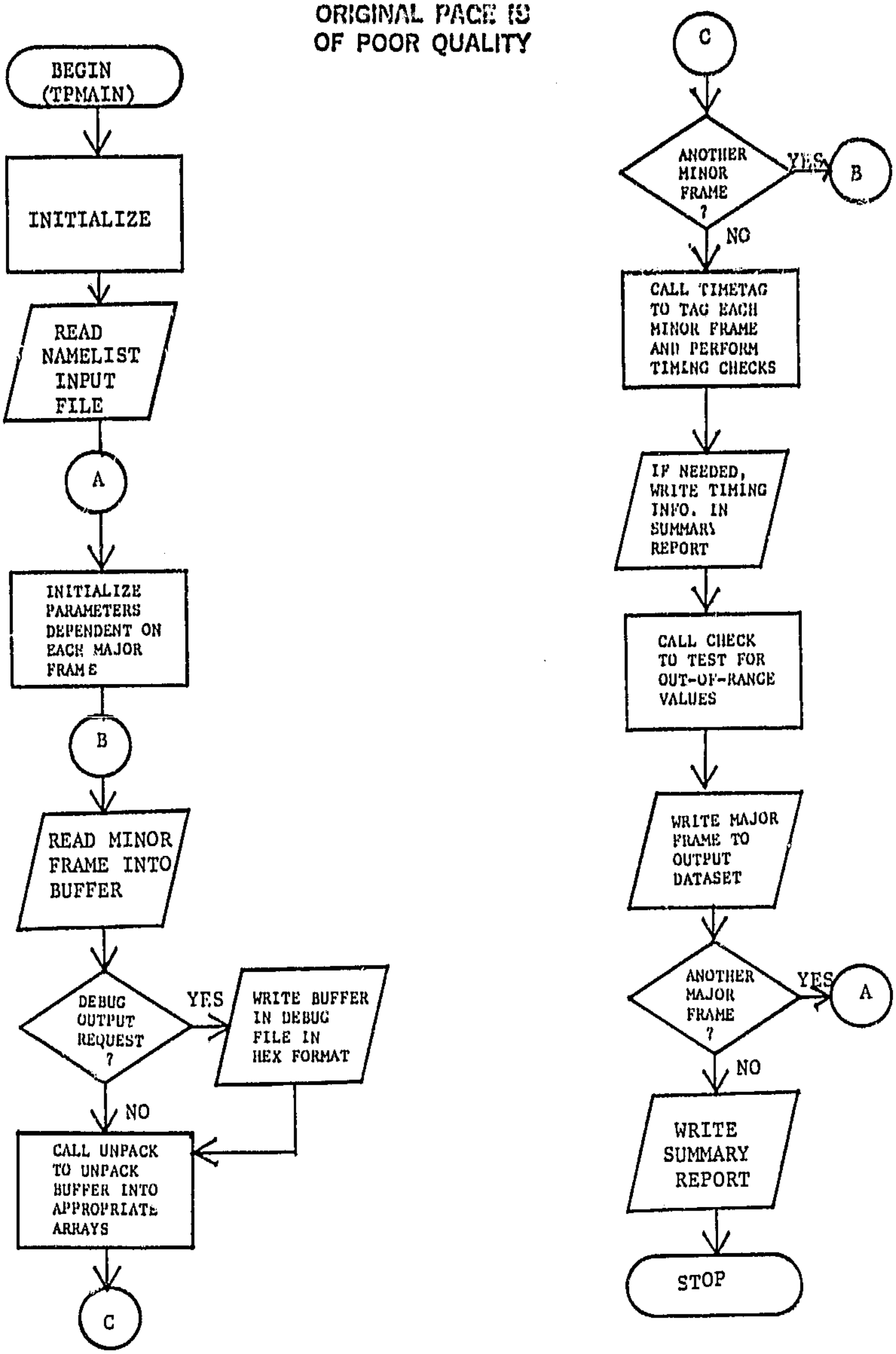

Figure 3-2 Telemetry Processor Flow Diagram

3.4 SUBROUTINE DESCRIPTIONS

The purpose, procedure, inputs, and outputs of the telemetry processor subroutines are described as follows:

TPMAIN

Purpose: TPMAIN serves as the driver of the Telemetry Processor.

Procedure:

(1) Intializes parameters and reads NAMELIST input file.
(2) Reads telemetry records into buffer.
(3) If requested, writes contents of buffer in debug output file in hexadecimal format.
(4) Calls UNPACK to unpack the buffer and load data into appropriate arrays.
(5) Calls TIMTAG to tag each record and perform time checking.
(6) Calls CHECK to test for out-of-range values and flag any that are found.
(7) Writes telemetry dataset in Telemetry Data Base.
(8) Writes summary report.

Input Parameters: None

Output Parameters: None

UNPACK

Purpose: UNPACK extracts the necessary data from the input buffer and stores them in the appropriate arrays.

Procedure:

(1) Checks the quality flag located in the first byte of the telemetry record buffer, BUFFER(1). If the flag is nonzero, the record is bad and missing value indicators are loaded into the data arrays.

(2) Unpacks the data that are in fixed locations on every record, i.e., data rate, sensor measurements.

(3) Depending on minor frame number, unpacks selected subcommutator data, i.e., OBC attitudes, ephemeris, other OBC reports.

Input Parameters:

BUFFER	Buffer containing one minor frame (128 bytes) of the telemetry stream.
NMINOR	Minor frame number.

Output Parameters:

IQUAL	Array containing qualilty flag of each minor frame: IQUAL(I)=0 Minor frame I contains valid data. =1 Minor frame I is missing.
IRATE	Array containing data rate indicator of each minor frame: IRATE(I)=1 Data rate is 1K-bps =8 Data rate is 8K-bps

ICSDAT	128 by 10 array containing sensor measurements from conical scanners 1 and 2 where Column 1 = Scanner1 Signal Status 2 = Scanner2 Signal Status 3 = Scanner1 Roll Fine Error 4 = Scanner2 Roll Fine Error 5 = Scanner1 Roll Coarse Error 6 = Scanner2 Roll Coarse Error 7 = Scanner1 Pitch Fine Error 8 = Scanner2 Pitch Fine Error 9 = Scanner1 Pitch Coarse Error 10 = Scanner2 Pitch Coarse Error
ITEMP	Array containing scanner temperatures for scanners 1 and 2
IBOLO	Array containing bolometer temperatures for scanners 1 and 2
ISENSR	Array containing sensor status flags for scanners 1 and 2
EPARMS	Array containing the OBC reference attitudes which are expressed as Euler parameters
MODES	Array containing mode flags from an OBC Report: MODES(1) = 1 Coarse sun acquisition = 2 Fine sun acquisition = 3 Stellar acquisition = 4 Earth pointing mode = 5 Inertial hold mode = 6 Slew mode = 7 Orbit MODES(2) = 1 Earth pointing mode = 2 Stellar pointing mode MODES(3) = 0 Ephemeris is from GPS = 1 Ephemeris is uplinked.

MODES(4) = 1 Stellar acquisition in progress
= 2 Stellar acquisition completed

EPHPOS Array containing ECI axis components of spacecraft position.

EPHVEL Array containiing ECI axis components of spacecraft velocity.

NOTE: The contents of EPHPOS and EPHVEL depend on the value of MODES(3).

DPUTIM Array containing the DPU time which is referenced to the start of each major frame.

TIMTAG

Purpose: TIMTAG attaches time tags to each minor frame and checks for anomalies in the timing information.

Procedure:

(1) Sets the current major frame start time using the DPU time data which is referenced to the major frame sync pulse.

(2) Checks the current major frame time against the previous reading to detect timing gaps or backtracking.

(3) Uses data rate information to compute time tags for each minor frame.

(4) Flags changes in data rate.

Input Parameters:

DPUTIM	Array containing DPU time data in days, hours, minutes, seconds, milliseconds
LASTIM	Initial time of previous major frame.
LSTRAT	Final data rate of previous major frame.
IRATE	Array containing data rate information for each minor frame in current major frame.

Output Parameters:

CURTIM	Initial time of current major frame.
TIME	Array containing time tages (in seconds since Sept. 1, 1957) for each minor frame.

CHECK

Purpose: Validate data and flag missing or out-of-range values.

Procedure:

(1) Check quality flags. If the total number of bad records exceeds the specified limit per major frame, write message in summary report.

(2) On each valid minor frame, test the contents of selected variables against validation criteria.

(3) Update running totals of missing or invalid values for each variable.

Input Parameters:

NMAJOR	Number of current major frame.
NMISS	Array containing running total of number of missing or out-of-range values for each variable that must be validated.
IQUAL	Array containing quality flag of each minor frame.
ICSDAT	128 by 10 array containing sensor measurements from scanners 1 and 2.
ITEMP	Array containing scanner temperatures for scanners 1 and 2.
IBOLO	Array containing bolometer temperatures for scanner 1 and 2.
ISENSR	Array containing sensor status flags.
EPARMS	Array containing OBC reference attitudes.
EPHPOS	Array containing ECI axis components of spacecraft position.
EPHVEL	Array containg ECI axis components of spacecraft velocity.

Output Parameters:

Missing value indicators are installed in the above arrays where needed. Updates are made to NMISS as needed.

SECTION 4 - SPECTRAL BANDPASS INTEGRATOR

4.1 FUNCTIONAL DESCRIPTION

The Horizon Radiance Data Base (HRDB) contains "average" Earth horizon radiance profiles. The radiances in these profiles are a function of four parameters: tangent height or zenith angle, latitude, time of year, and spectral band, i.e.,

$$R = F(H \text{ or } Z, EL, T, W)$$

where

H = tangent height in kilometers for lines of sight that pass above the horizon

Z = zenith angle in degrees for lines of sight that intersect the Earth

EL = Earth latitude

T = time of year

W = wavelength interval in microns.

The purpose of the Spectral Bandpass Integrator is to generate a new data base (LRDB) containing Landsat-D radiance profiles by integrating the HRDB radiances, with respect to the spectral transmission function of the Landsat-D conical scanner which is shown in Figure 4-1.

The computational procedure used in the Spectral Bandpass Integrator involves the following steps:

1. Using the conical scanner spectral transmission function, determine the weight to be applied to the radiance data for each spectral interval in the HRDB. The weight is the product of the spectral transmission and the band width i.e.,

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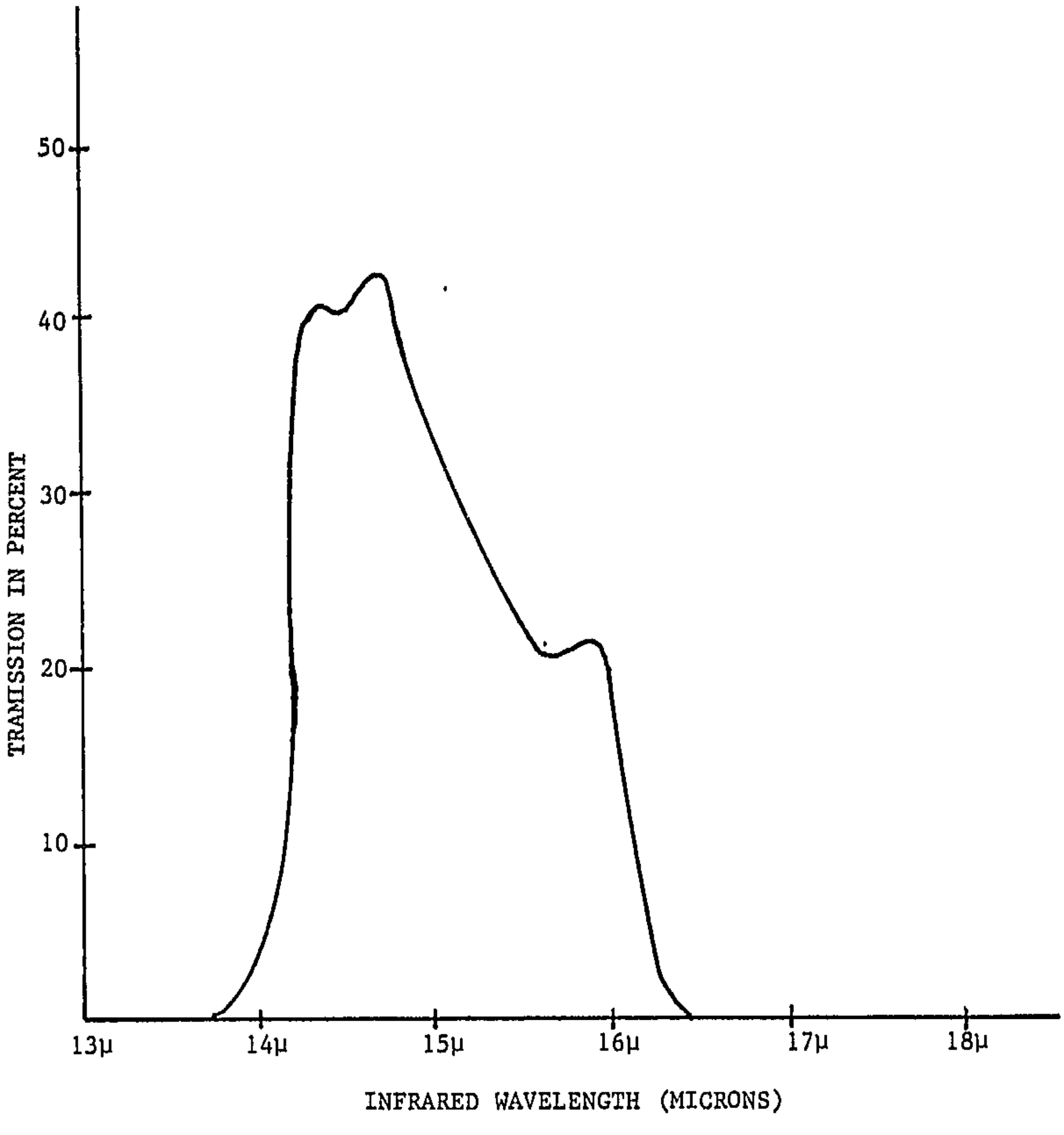

Figure 4-1 Spectral Transmission Function of the Landsat-D Conical Scanner.

$$\text{WEIGHT}(i) = \text{BANFUN}(i)*[W(i+1)-W(i)] \qquad (4\text{-}2)$$

where BANFUN(i) is the average transmission in the interval between W(i) and W(i+1).

2. For each tangent height or zenith angle, latitude, and season, compute the weighted sum of the radiances over the spectral bands, i.e.,

$$\text{RAD}(H \text{ or } Z,EL,T) = \sum_{i=1}^{NF} F(H \text{ or } Z,EL,I,W(i))*\text{WEIGHT}(I) \qquad (4\text{-}3)$$

for all H or Z, EL, and T

where NF is the number of frequencies or wavelengths in the HRDB

3. Enter the computed radiances and corresponding parameters in the Landsat-D Radiance Data Base.

4.2 INPUTS AND OUTPUTS

4.2.1 Namelist Inputs

The following lists the namelist input parameters included in the NAMELIST &SPBAIN.

BANFUN(i) (i=1,71)	Array containing the average spectral transmission corresponding to each wavelength interval in the HRDB
WSTART	Starting wavelength for bandpass integration (for Landsat-D WSTART = 13.6 microns)
WEND	Ending wavelength for bandpass integration (for Landsat-D WEND = 16.4 microns)
NHRDB	Unit number for HRDB
NLRDB	Unit number for LRDB
NPRINT	Unit number for printout

4.2.2 Dataset Inputs

The input radiance data to the Spectral Bandpass Integrator is from the Horizon Radiance Data Base (HRDB). This data base is described in Section 2.2.

4.2.3 Dataset Outputs

The output radiance data for the specified spectral bandpass is written to the Landsat Radiance Data Base (LRDB). See Section 2.3 for a description of the format and content of the LRDB.

4.3 SYSTEM STRUCTURE

The data flow for the SPBAIN is shown in Figure 4-2. Figure 4-3 provides a flow diagram of the system.

4.4 SUBROUTINE DESCRIPTIONS

The purpose, procedure, inputs and outputs of the SPBAIN subroutines are described as follows:

<u>SPMAIN</u>

Purpose: SPMAIN serves as the driver of SPBAIN.

Procedure:

(1) Read the input data from the NAMELIST and HRDB header record
(2) Read HRDB data records for a particular latitude and time
(3) Call TRAP tc provide the integration over the specified wavelength range
(4) Write one LRDB data record for a particular latitude and time and generate printout of the results
(5) Repeat steps 2 through 4 for all latitudes and times
(6) Write the LRDB header record

Input Parameters: NONE

Output Parameters: NONE

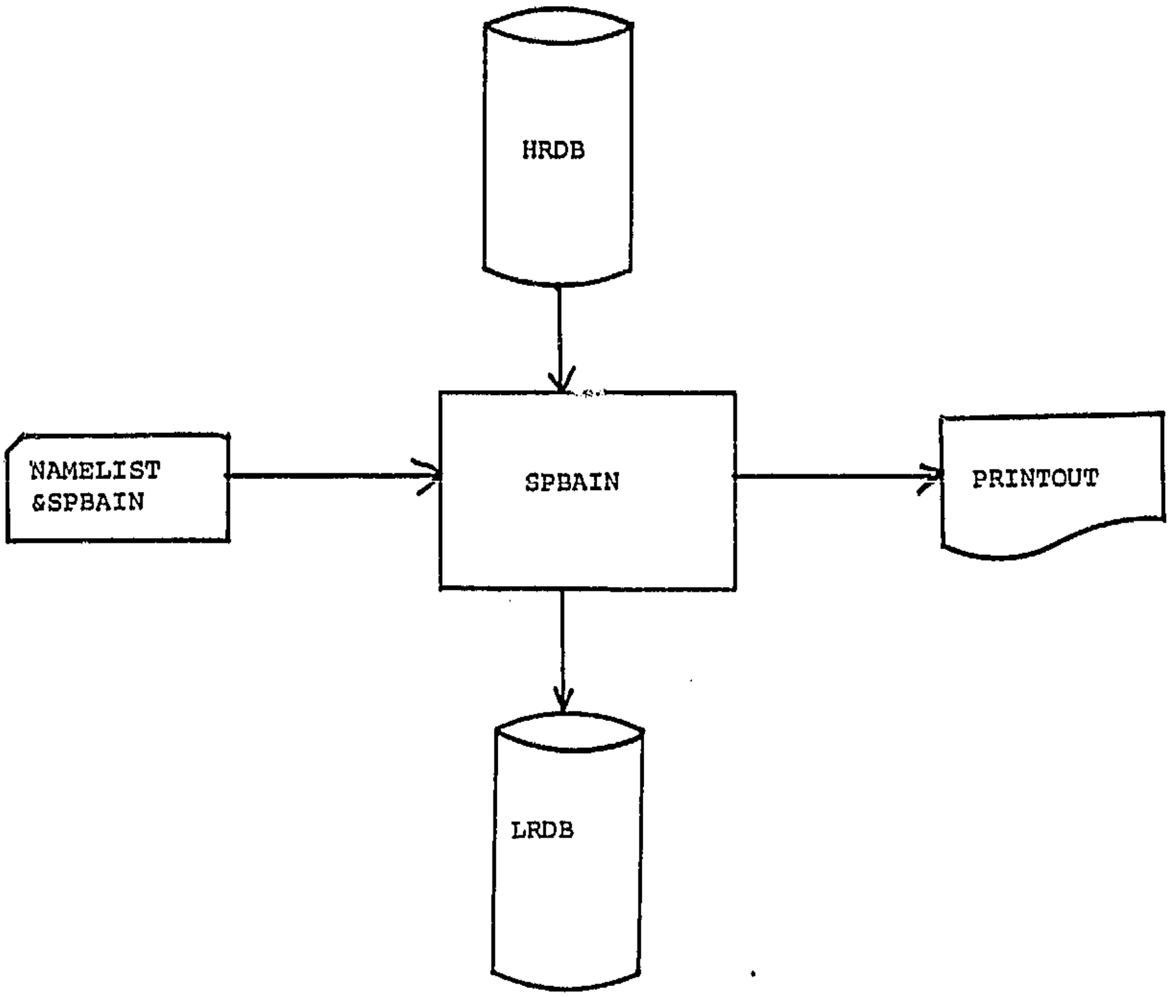

Figure 4-2 The Data Flow Diagram for SPBAIN

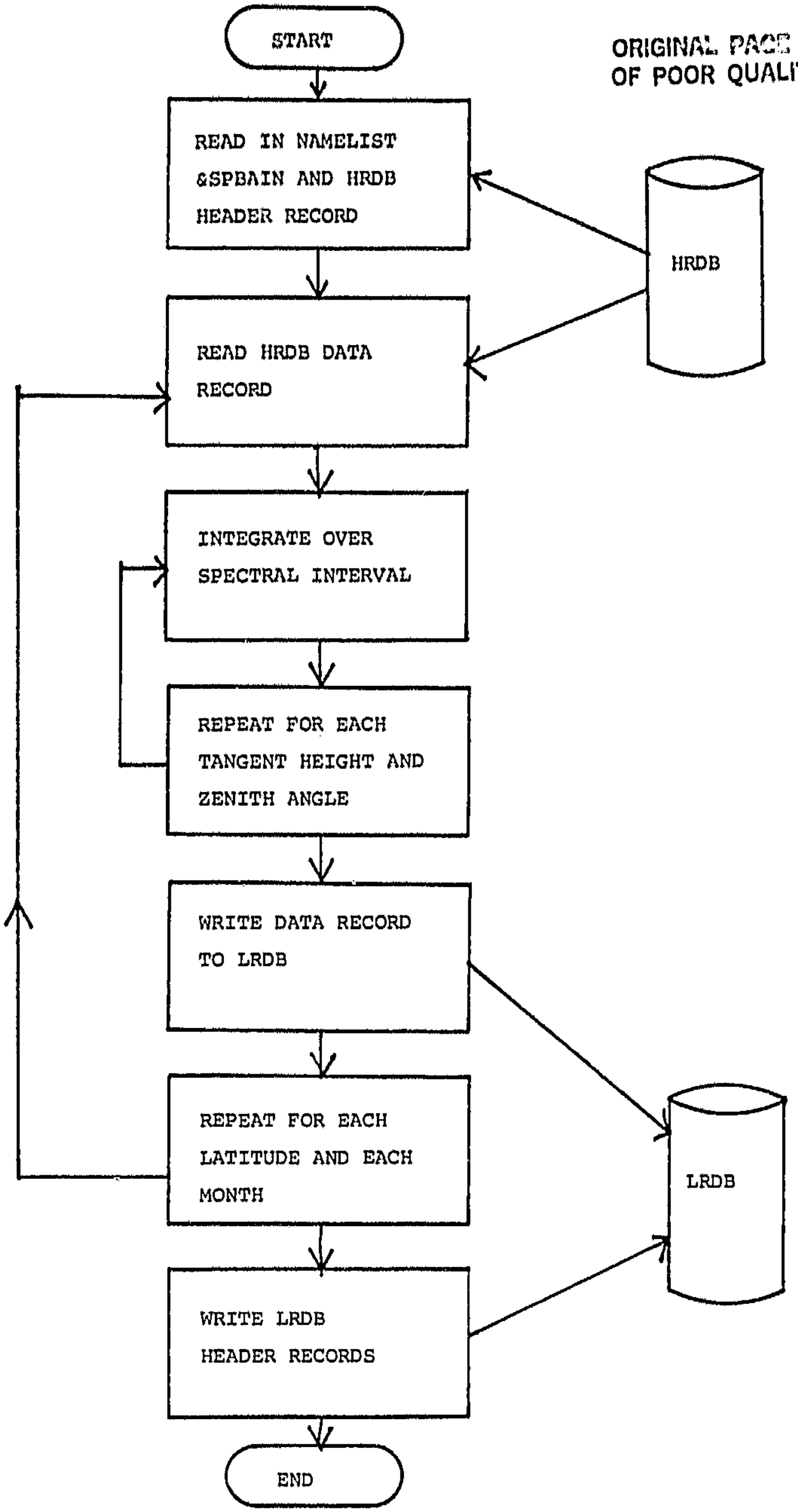

Figure 4-3 Flow Diagram of SPBAIN

TRAP

Purpose: TRAP is a subroutine that integrates over the specified range of the wavelength.

Procedure: Sum over the first element of a two dimensional array using an input array to weight each element, i.e.

$$\mathrm{RAD(k)} = \sum_{i=1}^{NF} \mathrm{R(i,k)*WEIGHT(i)} \qquad (4\text{-}4)$$

for all k.

Input Parameters:

BANFUN(i) (i=1,NF)	Array containing the spectral bandpass function
R(i,k) (i=1,NF) (k=1, NP)	Array of radiance profiles from one HRDB record.
NF	Number of wavelengths or frequencies
NP	Total number of tangent heights and zenith angles in the radiance profiles.

Output Parameters:

RAD(k) (k=1,NP)	Radiance profile integrated over the spectral bandpass

SECTION 5 - SENSOR OPTICS AND ELECTRONICS SIMULATOR (SOES)

5.1 FUNCTIONAL DESCRIPTION

The Sensor Optics and Electronics Simulator (SOES) is designed to estimate the effects of seasonal systematic radiance variation on the conical scanner measurements. A key input to this program is a data base describing the Earth radiance as seen by the Landsat-D conical scanner spectral bandpass. Other NAMELIST inputs describe the sensor optics and electronics and other modeling parameters. The key output is a database describing the apparent horizon triggering heights as a function of spacecraft position and season. This program is designed so that it may also be used as an analytical tool for studying the effects of various detailed model parameters on the sensor measurements.

A flow diagram of SOES is given in Figure 5-1. An outline of the computational steps is given below.

Step 1

The NAMELIST input is read and initialization computations are performed, including computation of impulse response function parameters (used in the convolution integral, step 5) from the transfer function parameters.

Step 2

The Landsat-D radiance profiles for a particular month are read from the LRDB and interpolated to 1 degree latitude increments.

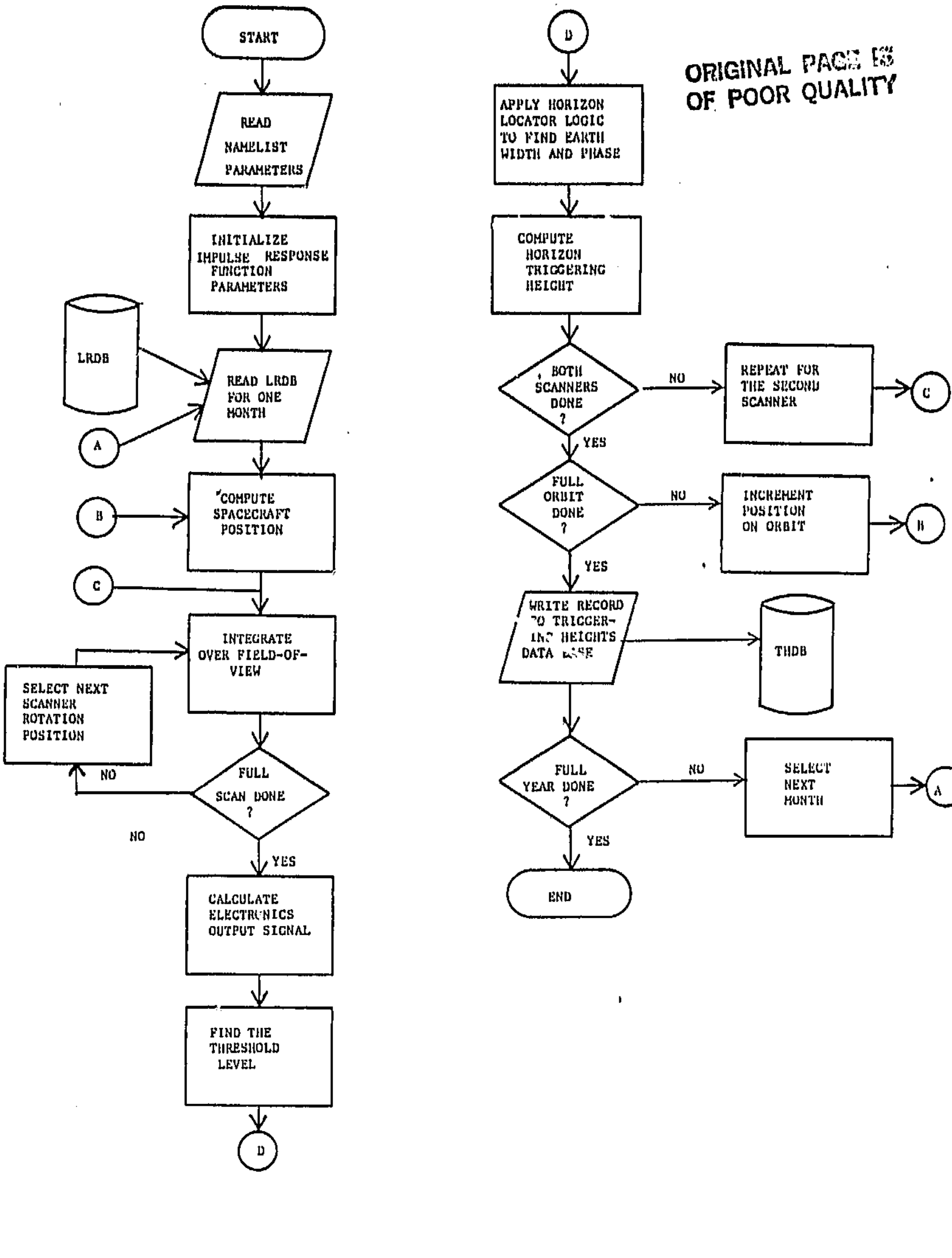

Figure 5-1 SOES Simulation Procedure

Step 3

The radiance is integrated over the bolometer field-of-view (FOV) to obtain the total incoming radiance to the bolometer. The radiance is assumed to vary in the direction normal to the Earth horizon. The FOV is assumed to be shaped like a parallelogram with sharp edges and with form and orientation dependent on the prism rotation angle.

Step 4

Steps 1 and 2 are repeated for each scan position in order to obtain the predicted input voltage signal as a function of time as the scanner sweeps across the Earth.

Step 5

This input voltage signal is convolved with the system impulse response function to obtain the predicted output voltage signal at representative times as the scanner sweeps across the Earth. The output signal will be similar to that shown in Figure 5-2.

Step 6

The electronincs output voltage signal as the scanner sweeps across the Earth is examined to obtain the maximum voltage, V_{max}, as the scanner enters the Earth and the minimum voltage, V_{min}, as the scanner leaves the Earth. Parobolic interpolation is used to obtain these values. These peak voltages are used to set the threshold levels for the next step.

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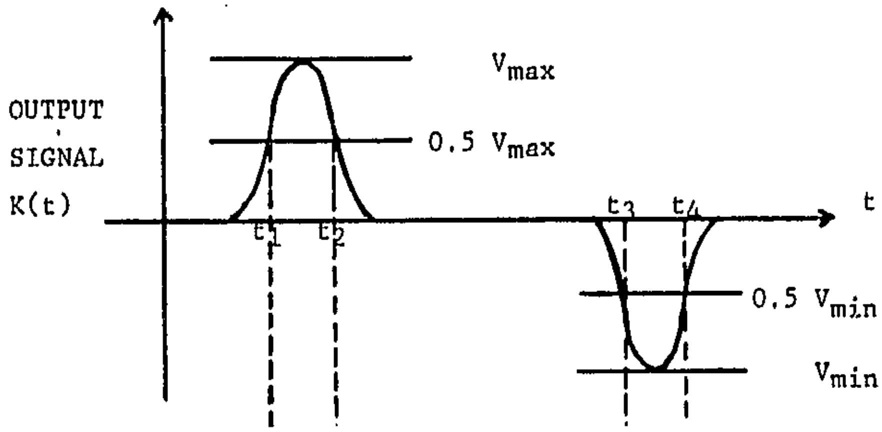

Figure 5-2 Landsat-D Electronics Output Signal and Threshold Level Crossings

Step 7

The threshold crossing times of the output signal, T_1 and T_2 for the Earth-in pulse, and T_3 and T_4 for the Earth-out pulse, are determined. Polynomial interpolation is done on the output signal and a Newton-Raphson iteration used to find the threshold crossing times.

Step 8

Based on the threshold crossing times, the scanner Earth-width and Earth-phase measurements are computed. These measurements are used to compute the apparent triggering heights at the horizon crossings.

Step 9

Steps 3 through 9 are repeated for each scanner.

Step 10

Steps 3 through 8 are repeated for each spacecraft position around the orbit. The results are written to the Triggering Heights Data Base (THDB).

Step 11

Steps 2 through 10 are repeated for each month of the year for which radiance data is available.

5.2 INPUTS AND OUTPUTS

5.2.1 Namelist Inputs

The NAMELIST input for SOES, &SOESIN contains the following variables.

<u>General Control Parameters</u>

IMODE Program flow mode

= 0 analysis mode, run for a selected month and time span

= 1 THDB generation mode, run for all twelve months for full oribts. IORBIT is automatically set to 1 to calculate orbit positions appropriate for the THDB

IMONTH Selected month number (1 to 12) for radiance data, used when IMODE = 0

<u>Earth Modeling Parameters</u>

RO Nominal Earth radius

HT Nominal horizon triggering height for ideal Earth

<u>Satellite Orbit Parameters</u>

IORBIT Orbit position selection option

= 0 use orbital elements and TSTART, TSTEP, TSTOP

= 1 use circular orbit with ASEMI and EYE and calculate orbit position appropriate for output to THDB

TSTART Starting time (YYMMDD.HHMMSS)

TEPOCH Orbit epoch time (YYMMDD.HHMMSS)

ASEMI Semimajor axis (kilometers)

E Eccentricity

EYE Inclination

EMO Mean anomaly

WO Argument of perigee

RANODE Right ascension of the ascending node

TSTEP Time step in calculating positions around the orbit (seconds)

TSTOP Stop time if full orbit is not desired (seconds)

Scanner Parameters

AZI(i) (i=1,2) Azimuth angles for scanners 1 and 2

TILT(i) (i=1,2) Tilt angles for scanners 1 and 2

TWIST(i) (i=1,2) Twist angles for scanners 1 and 2

GAM(i) (i=1,2) Cone angles of FOV center from scan-axis for scanners 1 and 2

SPIN(i) (i=1,2) Spin rates for scanners 1 and 2

Radiance Profiles Expansion Parameter

NPTSL Number of points to be used in the Euler-Lagrange interpolation over latitude at fixed values of tangent height and zenith angle.

Incoming Signal Computation Parameters

NPHI Number of scanner rotation angles for which the incoming radiance is calculated (NPHI $\leq$ 200)

PHI(i) (i=1,200) Scanner rotation angles for which the total incoming radiance is calculated.

Field-of-View Integration Parameters

FOVSIZ	Width of scanner square field-of-view prior to distortion by prism (degrees)
FOVSTR	Stretching factor of field-of-view due to prism distortion
FOVORI	Rotational orientation of the square bolometer flake with respect to the scanner y-z axis (degrees)
NPTSZ	Number of interpolation points for radiances to be used in Euler-Lagrange interpolator at fixed value of latitude and input value of zenith angle
NPTSH	Number of interpolation points for radiance to be used in Euler-Lagrange interpolator at fixed value of latitude and input value of tangent height

Electronic Transfer Function Parameters

RADVOL	Radiance to volts conversion factor
ATB	Magnitude of scan angle whose negative corresponds to the time at the limit of the convolution integral
TMAXIN	Maximum time period for the convolution integral
THRESH	Ratio of triggering signal to maximum signal
NPTSI	Number of points to be used in the interpolation on the electronics input signal

Threshold Calculation Control Parameters

E1
E2
B1
B2
A1 Coefficients of the transfer function
A2
A3
A4
A5
A6

ESP	Constant specifying the degree of convergence in the Newton-Raphson procedure for locating the threshold
IEND	Maximum number of iterations in RTNI
DELTAT	Time offset for the computation of the numerical derivative for the Newton-Raphson procedure
NPTSO	Number of points to be used in the interpolation on the electronics output signal.

Input/Output Control Parameters

IPLOT	Plot input/output signal = 0 no plot = 1 plot input and output impulse = 2 above and intermediate result
IFTOUT	Printout unit number for result
IFTDEB	Printout unit number for debug
ILRDB	Fortran unit number for LRDB input data file
ITHDB	Fortran unit number for THDB output data file

ILEVEL(i)	Debug level for i-th subroutine printout
(i=1,30)	= 0 no printout at all
	= 10 start/end messages and parameters
	= 20 above and input/ouput parameters
	= 30 above and intermediate result
	= 40 above and debug type 1 messages

5.3 SYSTEM STRUCTURE

The data flow for the SOES is illustrated in Figure 5-3. Input to SOES consists of the NAMELIST parameters and Landsat-D radiance data (LRDB). Output from SOES includes triggering heights data versus subsatellite latitude which is written to the Triggering Heights Data Base (THDB). The SOES consists of a main program and orbit generator, an interpolator, an integrator, and various subprograms. The analytical basis for various subprogram computations is described in Reference 4. Figure 5-4 illustrates the program structure.

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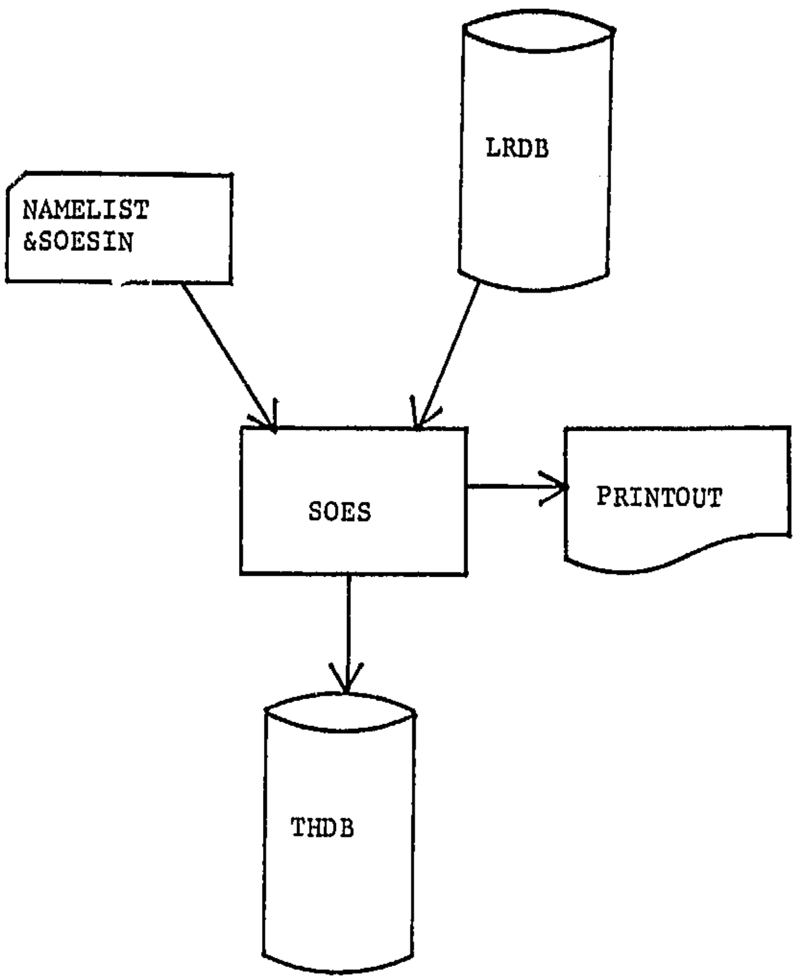

Figure 5- 3 SOES Data Flow

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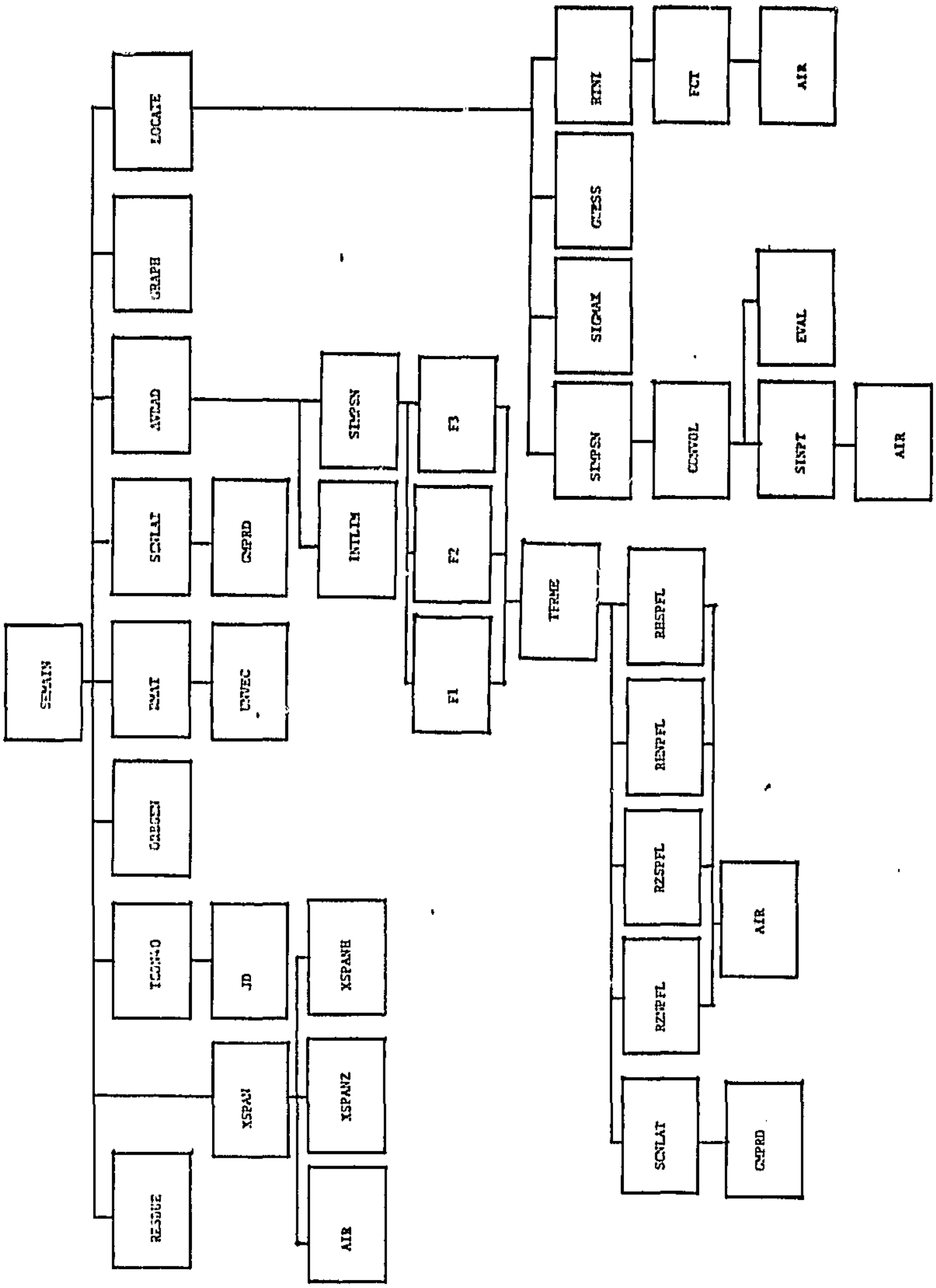

Figure 5-4 SOES Baseline Diagram

5.4 SUBROUTINE DESCRIPTIONS

The Sensor Optics and Electronics Simulator subroutines are described as follows. Brief descriptions of the purpose of the existing subroutines are included. The existing subroutines are taken from Reference 5.

SEMAIN

Purpose: SEMAIN is the driver of the Sensor Optics and Electronics simulator.

Procedure:

(1) A card image copy of the NAMELIST input dataset is written out and the NAMELIST input is read. If the program is in analysis mode (IMODE=0) it is set up to run for a particular time of year, otherwise (IMODE=1) is set up to loop though all the months of the year and write to the Triggering Heights Data Base.
(2) Call subroutine RESDUE to intialize the impulse response function parameters.
(3) Read the LRDB for a particular month.
(4) Call subroutine ORBGEN to compute the spacecraft position.
(5) Compute the scan axis attitude.
(6) Compute the field-of-view center line-of-sight.
(7) Call subroutine AVRAD to calculate the radiance over the field-of-view.
(8) Repeat steps 6 through 7 for the next scanner rotation position until the full Earth scan is done.
(9) Call subroutine LOCATE to compute the output signal from the electronics, and apply the horizon locator logic to find the Earth-in and Earth-out crossing angles.
(10) Calculate the horizon triggering height.
(11) Repeat steps 5 through 10 for the second scanner.
(12) Repeat steps 4 through 11 for the next spacecraft position until a full orbit is done or the [illegible] time is reached.
(13) Store the results (triggering heights) in THDB.
(14) If IMODE=1, repeat steps 3 through 13 for the next month until the full year is done.

Input Parameters: None

Output Parameters: None

RESDUE

Purpose: Subroutine RESDUE initialize the constants for the impulse response function.

Procedure: The value of various parameters used in the transfer function (see formulas in Appendix A, Reference 4) are passed to RESDUE via common block /POLES/ to calculate coefficients for the impuse response function.

Input Parameters:

Through common block /POLES/ - Coefficients for the transfer function

E1, E2, B1, B2, A1, A2, A3, A4, A5, A6

Output Parameters:

Through common block /POLES/ - Coefficients for the impulse response function

AI1, AI2, AI3, AI4, AI5, AI6, ALFA7, ALFA8, BI1, BI2 CI1, CI2

XSPAN

Purpose:

XSPAN accepts radiance data for latitudes of -80 degrees to +80 degrees at 20 degree increments. It interpolates radiance data for latitudes from -90 degrees to +90 degrees at 1-degree increments and stores the results in 181-column arrays. An interpolation routine AIR that uses Aitken's recursive method is used to perform the interpolations.

AIR

Purpose:

AIR (Aitken's interpolation routine) interpolates on input "X" and "Y" tables by fitting a polynomial to an input number of points in the tables using Aitken's recursive method. The points chosen for the polynomial fit are those nearest the X value which is input for interpolation. The output is the interpolated Y value which corresponds to the input X value.

XSPANZ

Purpose:

XSPANZ stores the interpolated radiance data versus zenith angle received from XSPAN into common blocks for use by the subroutines RZNPFL and RZSPFL. The data are stored in 1-degree increments from 90°S to 90°N for all zenith angles.

XSPANH

Purpose:

XSPANH performs the same function as XSPANZ except that it stores the data for the tangent heights into common blocks for use by the subroutines RHNPFL and RHSPFL.

TCON40

Purpose:

TCON40 converts time in YYMMDD.HHMMSSMMM to time in seconds from September 1, 1957, at 0 hours UT.

JD

Purpose:

JD converts calendar days in the format YYYYMMDD to Julian day (days since January 2, 4713 BC).

ORBGEN

Purpose:

ORBGEN is a Keplerian orbit generator. It accepts time and orbital elements and generates the spacecraft positon and velocity in geocentric inertial coordinates.

RMAT

Purpose:

RMAT computes the inertial-to-orbital coordinates transformation matrix. It accepts spacecraft position and velocity vectors and outputs rotation matrices from orbital to geocentric inertial coordinates (GCI) and from GCI to orbital coordinates.

UNVEC

Purpose:

UNVEC unitizes a vector. It accepts a vector of nonzero magnitude and provides a unit vector in the direction of the original vector and a scalar that equals its magnitude.

SCNLAT

Purpose:

SCNLAT calculates the latitude corresponding to the center of the scanner FOV, using the scanner ID and spacecraft ephemeris and assuming a spherical Earth with pitch, roll, and yaw equal to zero.

GMPRD

Purpose:

GMPRD computes a general matrix product.

AVRAD

Purpose: AVRAD computes the average radiance over the scanner's FOV taking into account the variation in radiance over the FOV (Equation 4-9 through 4-10 in Reference 4). The atmosphere is assumed to be composed of shells of equal radiance such that an isoradiance contour that is concentric with the Earth's surface can be defined. This reduces the field-of-view averaging to a single-dimension integral, perpendicular to the isoradiance contour. The equations for this computation are discussed in Reference 4, Section 4.3.2.

Procedure:

(1) Call INTLIM to compute parameters U and KCI that define upper and lower limits for the FOV integrals.

(2) Call SIMPSN three times to calculate three integrals with different limits and the different external functions F1, F2, and F3, to complete the field-of-view integration in three pieces.

(3) Sum up the total radiance over the field-of-view.

Input Parameters:

PHIIN	Scanner rotation angles
ID	Scanner identification (1 or 2)

Through common block /FOVPAM/

FOVS1Z FOVSTR FOVORI NPTSL NPTSH	Field-of-view integration parameters

Output parameters:

RAD The radiance averaged over FOV

INTLIM

Purpose: Subroutine INTLIM calculates the parameters U and KCI that are used by Simpson's integration procedure as upper and lower limits.

Procedure:

(1) Calculate the angle ALFA between the direction of the scan path and isoradiance normal vector $\vec{R}$ (Equation 4-9, Reference 4)

(2) Calculate U and KCI (Equation 4-10 in Reference 4)

Input Parameters:

GAMMA	Cone angle of FOV center from scan-axis
RO	Nominal Earth radius
FOVSIZ	Width of scanner square field-of-view prior to distortion by prism (degrees)
FOVSTR	Stretching factor of field-of-view due to prism distortion
FOVORI	Rotational orientation of the square bolometer flake with respect to the scanner y-z axis (degrees)
ETA	Separation between Earth center and scan axis (degrees)

Output Parameters:

U	Distance from the FOV center to the farthest edge of the FOV, projected on the direction that the radiance changes.
KCI	Distance from the FOV center to the FOV corner point projected on the direction that the radiance changes.

F1, F2, F3

Purpose:

F1, F2, F3, are the external functions that provides the first, second and third integral in the subroutine AVRAD in Section 5.4.13.

$$F_1 = (U+X)R(X)$$

$$F_2 = R(X)$$

$$F_3 = (U-X)\ R(X)$$

Input parameters:

X - integration variables

U - integration parameters from subroutine AVRAD

Output parameters:

F1,F2,F3 Function value evaluated at X

SIMPSN

Purpose:

SIMPSN is a utility subroutine that performs an integration over an input function over a specified range.

Method:

The integral is evaluated using Simpson's integration rule.

Input Parameters:

AA - uppper limit of integration

BB - lower limit of integration

NPT- number of the integration points

FX - external function name that evaluatesthe integrand

Output parameters:

ANS - value of integral

RZSPFL

RZSPFL accepts equivalent scanner latitude and zenith angles. It accepts 90 radiance profile vectors covering the latitudes of 90 degrees to 1 degree at 1-degree intervals. RZSPFL finds the vector closest to the scanner latitude and interpolates on the vector elements to find the radiance corresponding to the given zenith angle. It is used only for southern latitudes.

RHSPFL

RHSPFL is the same as RZSPFL, except that it operates on tangent heights rather than zenith angles.

RZNPFL

RZNPFL is the same as RZSPFL, but for northern latitudes. There are 91 columns (the Equator is included).

RHNPFL

RHNPFL is the same as RHSPFL, but for northern latitudes. There are 91 columns (the Equator is included).

GRAPH

GRAPH is a general line printer plot subroutine. It is used by SOES to make plots of the electronics input and output signals and the triggering heights output.

LOCATE

Purpose:

The subroutine LOCATE obtains the output signal from the sensor electronics, and determines the horizon crossing positions that are measured by the sensor.

Procedure:

(1) Calls the subroutine SIMPSN with the external function CONVOL to convolve the input signal to the bolometer with the impulse response function to obtain the output voltage from the electronics. The call to SIMPSN is repeated to obtain a table of the output voltage as a function of time.

(2) The subroutine SIGMAX is called to obtain the peak signal in the Earth-in horizon crossing.

(3) The voltage threshold level is determined as a fixed percentage of the peak signal.

(4) The subroutine GUESS is called to obtain initial estimates for the threshold crossing times.

(5) The subroutine RTNI is called to determine each of the two threshold voltage crossing times for the Earth-in crossing.

(6) Steps 2 through 5 are repeated except to find the threshold voltage crossing times for the Earth-out horizon crossing.

(7) The threshold voltage crossing times are used to compute the scanner rotation angles at the horizon crossings.

Input Parameters:

PHI	Array containing the scanner rotation angles at which the incoming radiance is computed.

RADAV   Array containing the radiance averaged over FOV

NPHI   Number of points in arrays PHI and RADAV

Output Parameters:

PHITRG   Array containing the triggering rotation angles

CONVOL

Purpose: CONVOL is a FORTRAN FUNCTION subprogram that is used by subroutine SIMPSN as an external function and provides the intregand of the convolution integral.

Procedure:

(1) Calls the subroutine SINPT to obtain the input electronic signal function at the time TPRIME

(2) Calls the subroutine EVAL to evaluate the impulse response function at the time difference between TPRIME and T which is the time at which the output voltage is being computed.

(3) Calculates the product between the input electronic signal function for the given time and the impulse response function for the time shift from T.

Input Parameters:

TPRIME Argument of the function

Through common block /LIMIT/

T Time for which the output voltage is being computed

Output Parameters: None

SINPT

Purpose: SINPT evaluates the input voltage to the signal processing electronics at a given time.

Procedure:

(1) The scanner rotation angle, PHIT, at the input time is calculated using the scanner spin rate.

(2) The subroutine AIR is called to obtain the average incoming radiance at the rotation angle PHIT by interpolating on the radiance vs. scanner rotation angle table.

(3) The incoming radiance is converted to a voltage by using the NAMELIST parameter RADVOL

Input Parameters:

TIME	Time at which to evaluate the input voltage to the signal processing electronics
RATE	Spin rate of the scanner
RADVOL	Radiance to volts conversion factor

Output Parameters:

SIGNAL	Input signal to the electronics in volts.

EVAL

Purpose: Subroutine EVAL evaluates the impulse response function for a given time.

Procedure: The coefficients for the impulse response function were calculated by subroutine RESDUE and saved in common block /POLES/. These coefficients are used to calculate the impulse response function (Appendix A, Reference 4).

Input Parameters:

TPRIME Argument of the impulse response function

Through common block /POLES/ - Coefficients for impulse response function.

AI1, AI2, AI3, AI4, AI5, AI6, ALFA7, ALFA8, BI1, BI2, CI1, CI2

Output Parameters:

TRF Impulse response function calculated for the given time

SIGMAX

Purpose: The subroutine SIGMAX calculates the maximum or minimum of the electronic output voltage signal and obtains the voltage threshold level. The array containing the output voltages are searched until three points around the maximum (or minimum) is found. Then parobolic interpolation is used to find the maximum (or minimum).

Procedure:

(1) The search procedure starts with the array index I set equal to the input variable INDEX1.

(2) The three consecutive points ANS(I), ANS(I+1) AND ANS(I+2) are evaluated for the maximum or minimum condition.

(3) The array index I is incremented by one and step 2 is repeated until the three maximum or minimum points are found.

(4) The time of the maximum (or minimum) TMAX, and the maximum (or minimum) value ANSMAX is found by fitting a parabola to the three points T(I), ANS(I), for I=1,2,3.

(5) The threshold level TRLEV is computed as a fixed fraction of the maximum (or minimum) value ANSMAX

Input Parameters:

INDEX1	Array index at which to start search for the maximum.
T	Array of time values
ANS	Array of electronics output signal values
ISIGN	Max or Min search option. If ISIGN is less than zero the program searches for a minimum.
THRESH	Threshold coefficient

Output Parameters:

IMAX	Array index nearest the maximum (or minimum) point
TRLEV	Threshold level
TMAX	Time associated with maximum
ANSMAX	Estimate of maximum value of ANS array

GUESS

Purpose: The subroutine GUESS finds the initial estimate of the threshold crossing time for beginning the Newton-Raphson iterative procedure.

Procedure:

(1) The search procedure starts from array index associated with the maximum voltage point in the electronics output voltage array, ANS.

(2) The array index is decreased until the signal value becomes less than threshold value (or greater than threshold value if ISIGN is less than zero). This array index provides the pointer to the initial time estimate for the Newton-Raphson iterative procedure.

(3) Step 1 through 2 are repeated except that the array index increased.

Input Parameters:

TRLEV	Threshold level
ANS	Array containing electronics output signal
IMAX	Array index of the maximum point
ISIGN	Positive or negative crossing search option. If ISIGN is less than zero the array indices are changed until the array value is <u>above</u> the threshold.

Output Parameters:

ICROSS(2) Array indices nearby the threshold crossings

RTNI

Purpose: The subroutine RTNI solves for the zeros of a function given an intial guess by using the Newton-Raphson iteration scheme. The external reference FCT provides the function value and its derivative to RTNI.

FCT

Purpose: FCT is a subroutine that calculates the value of the derivates whose zeros are found by the Newton-Raphson iterative procedure, RTNI. FCT evaluates the electronics output signal by calling AIR to interpolate on the tables of the output voltages vs. time. The function value returned by FCT is the output signal minus the threshold level. The output signal derivative is evaluated numerically.

SECTION 6 - SCANNER MEASUREMENT PREDICTOR

6.1 FUNCTIONAL DESCRIPTION

The Scanner Measurement Predictor (SMP) performs the following functions:

(1) Simulates the sensor measurements from each Landsat-D conical scanner based on given ephemeris and reference attitude data.

(2) Generates a dataset containing spacecraft position and attitude information and one of the following

Mode A. (Predicted/Observed). Predicted horizon scanner measurements along with actual measurements obtained from the Telemetry Data Base

Mode B. (Predicted/Predicted). Measurements predicted from two sets of model parameters

(3) Generates basic statistics on the information written to the output dataset.

(4) Generates a printout containing the predicted horizon crossing positions on the Earth.

The output dataset is read by the Data Plotting and Fitting Utility in support of the sensor evaluation activities.

To obtain the predicted measurements, the SMP first computes scanner measurements by modeling the intersection of the scan cone with an ellipsoid or oblate Earth assuming nominal conditions, and then applies corrections to these initial estimates. The correction factors simulate various error sources including misalignment of the scanner, responses of the sensor optics and electronics to variations in Earth horizon radiance, sensor output voltage and telemetry calibrations, sensitivity of the scanner measurements to temperature changes, and presence of random noise.

The two prediction modes A and B are for inflight data and theoretical analysis respectively. Mode A is the basic operational mode for inflight data analysis. It provides a dataset from which the residual errors between the observed and predicted measurements can be plotted and analyzed. Mode B is provided for convenient analysis of the effects of sensor model parameter variations. For example, this mode can be used to show the corrections to the scanner measurements due to effects of Earth oblateness and horizon radiance variations. More generally, this mode can be used to show the effects of any sensor model parameter changes that are considered for analysis purposes. After the output dataset is generated in this mode, the Data Plotting and Fitting Utility can be run to readily provide plots of the effects of the parameter changes as a function of time or other available parameter. Data fitting to the mode B output also provides an important system capability. In particular, the effects of systematic horizon radiance variation as predicted by the SOES utility and stored in the Triggering Heights Data Base can be fit by selected finite Fourier series parameters to provide an analytical representation of these effects. The systematic horizon radiance variation effects can be fit two ways, as a function of orbit position, and as a function of horizon crossing latitude.

Figure 6-1 diagrams the basic procedure used in the SMP. Each of the steps in the diagram are described below. Reference 4 contains a full description of the mathematics of the model.

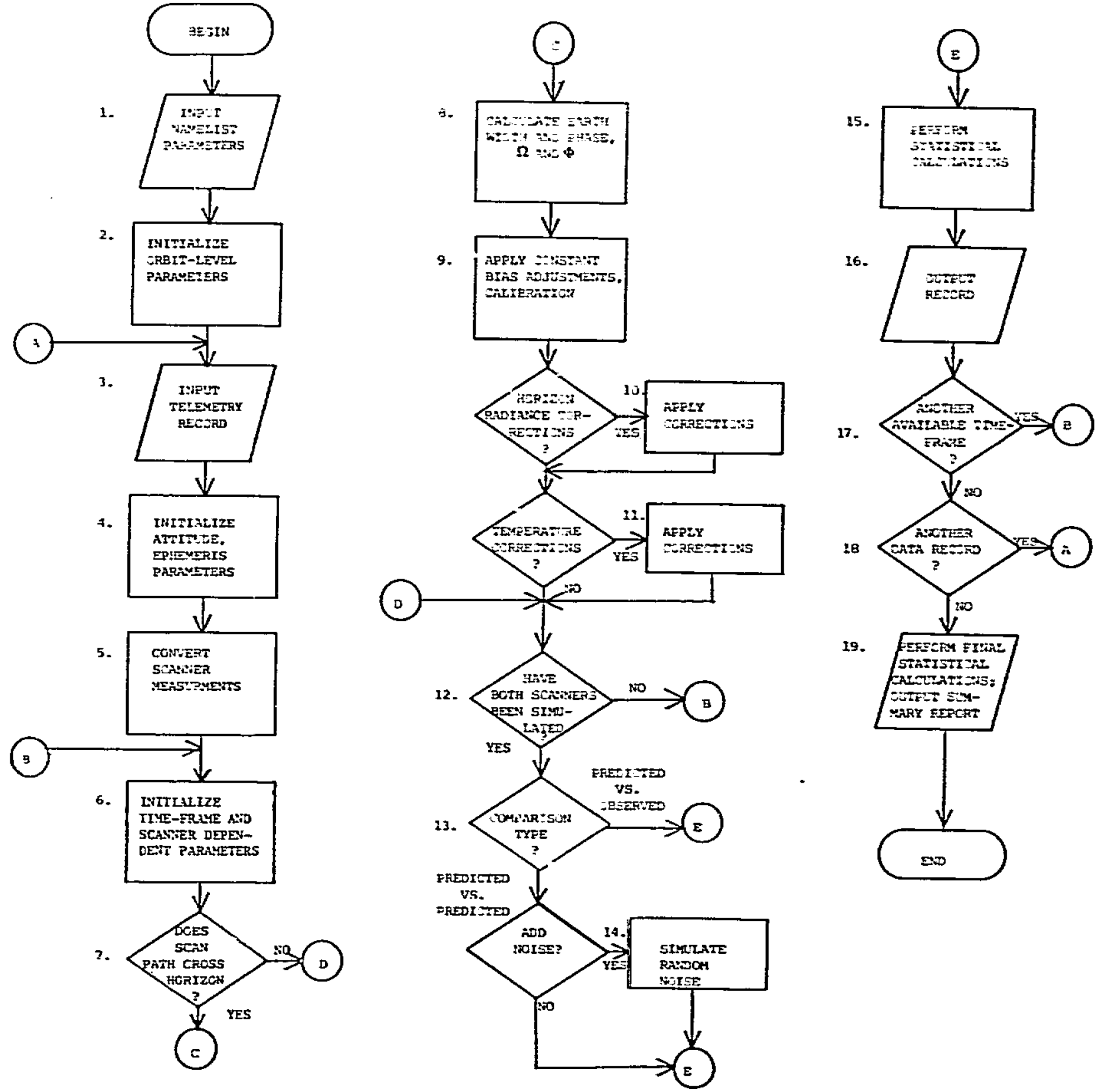

Figure 6-1 Scanner Measurement Predictor Flow Diagram

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Step 1

The model parameters are read from a NAMELIST input file. The parameters include data needed for simulation of error sources as well as control information that indicates which input/output options have been selected. Section 6.2.1 lists the NAMELIST parameters in detail.

Step 2

The following parameters, which do not change throughout the simulation, are initialized:

1. CONE (i) - scan cone radial arc length from $scanner_i$ spin axis
2. AZIM (i) - $scanner_i$ mounting alignment azimuth angle
3. TILT (i) - $scanner_i$ mounting alignment tilt angle
4. TWIST(i) - $scanner_i$ mounting alignment twist angle
5. SMOUNT (3,3,i) - spacecraft body to $scanner_i$ coordinates transformation matrix

The subscript i indicates that these parameters are needed for both scanner 1 and scanner 2.

Step 3

If the ephemeris or attitude data are obtained from the Telemetry Data Base, or if the output dataset is to contain predicted vs. observed measurements (as opposed to predicted vs. predicted measurements), the Telemetry Data Base is read in this step.

One record is read from the Telemetry Data Base at a time. Each record contains 4 OBC reference attitudes, 4 ephemeris, and 128 scanner pitch and roll measurements. See Section 2.1.2 for a detailed description of the telemetry record.

Step 4

The reference attitude and ephemeris data are initialized. There are two possible sources for the reference attitudes:

(1) Telemetry Data Base - These are the OBC attitudes that are input as Euler parameters.

(2) Constant Pitch, Roll, Yaw - The pitch, roll, and yaw parameters are obtained from the NAMELIST input file.

There are also two sources for the ephemeris:

(1) Telemetry Data Base - The telemetry contains the spacecraft position and velocity vectors in GCI coordinates.

(2) Ground Ephemeris - There is a utility program called EPHEMX that reads a NASA standard ephemeris tape or uses NAMELIST input orbital elements.

If either the attitude or ephemeris data are obtained from the Telemetry Data Base, the system defaults to using the telemetry timing information also. In this case, there is an additional option to interpolate the attitude/ephemeris measurements, which are available at a rate of 4 samples per major frame, to enable a full comparison with the scanner measurements which are sampled 128 times per major frame. If this option is selected, the interpolation is performed in this step by a simple linear method.

Step 5

The scanner measurements are initially in the form of voltage outputs. The voltages are converted to counts when they are downlinked the telemetry stream. The Telemetry Processor stores the measurements in the Telemetry Data Base in this form.

In this step, the scanner pitch and roll measurements are converted to angular Earth width and phase, and scanner and bolometer temperature measurements are converted to degrees centigrade.

Step 6

The following parameters must be initialized for every new measurement prediction:

1. ATT(3,3) - orbital to spacecraft body coordinates transformation matrix (specified by pitch, roll, yaw)
2. ORBNRM(3) - orbit normal direction
3. GCIORB(3,3) - geocentric inertial to orbital coordinates transformation matrix
4. GCISC(3,3) - geocentric inertial to S/C Body coordinates transformation matrix
5. ES(3,i) - scanner $_i$ to Earth center direction
6. ETA(i) - arc-length separation between scanner$_i$ spin axis A and Earth vector E
7. SUBLAT - latitude of subsatellite point
8. RSUB - Earth radius at subsatellite point
9. RHO(i) - Earth angular radius as seen from S/C
10. SPINAX(3,i) - Scanner$_i$ spin axis

The subscript i indicates that the parameter is dependent on the scanner number.

Step 7

A test is made to see whether or not the scan path crosses the Earth horizon. If not, the scanner measurements cannot be predicted. Flag values will be entered in the output in this case.

Step 8

The initial estimates of the Earth width and phase angles are calculated. The method used in the calculations involves iteratively computing horizon crossing positions on an ellipsoid model of the Earth. The initial estimates of Earth width and phase are adjusted according to the following constant bias parameters:

1. Constant adjustment to the horizon radiance height that triggers the sensor
2. Constant adjustment to the Earth angular radius which models the effects due to finite sensor field-of-view
3. Constant adjustments to the Earth width and phase angles which model effects due to sensor electronics (e.g., circuit response delays or errors in the amplifier gains). These corrections are applied in the form of a polynomial with user-specified coefficients.

Step 10

In this step, the initial estimate for Earth width and phase are adjusted to account for sensor responses to systematic variations in Earth horizon radiance. The correction factors usually are obtained from the Triggering Heights Data Base which is generated by the Sensor Optics and Electronics Simulator. An alternative to using the data base is to supply an analytic function that represents the contents of the data base. If no adjustments from the Triggering Heights Data Base are desired, this step can be skipped.

Step 11

Temperature dependent biases can be modelled by adding correction factors that are computed as a function of the temperature data available in the Telemetry Data Base.

Step 12

Steps 6 through 11 are performed twice, i.e, once for each scanner. If both scan paths do not cross the horizon, steps 13 through 16 described below should be skipped.

Step 13

If the comparison type is predicted vs. predicted, steps 6-12 must be repeated to obtain the second set of predicted measurements.

Step 14

In the case in which the output dataset is to contain predicted measurements vs. predicted measurements, it is possible to simulate the presence of random noise in one set of measurements. This option enables the comparison of "ideal" measurements with simulated noisy measurements.

Step 15

The residual errors between the predicted measurements and observed measurements (or second set of predicted measurements) are calculated. All computations necessary to obtain the basic statistics for the summary report are made. The basic statistics include the mean residual error, root-mean-square residual error, and an estimate of the standard deviation of the residual errors as well as the minimum, maximum, and mean of the predicted and observed Earth width and phase measurements, scanner temperature, bolometer temperature, reference attitude, and spacecraft altitude.

Step 16

As each set of predicted measurements is computed, it is added to the output dataset. Note that steps 6 through 12 are performed twice, i.e. once for each scanner. Thus each output record contains all relevant measurements for both scanners. The SMP optionally generates a printout of the horizon positions viewed by the scanners as a function of time. The Horizon Positions printout aids in the empirical evaluation of the effects of cold clouds on the scanner measurements. The computed horizon positions are based on the reference attitude and on the NAMELIST input parameters DHIN and DHOUT. The NAMELIST parameters IPRNT determines whether or not the Horizon Positons printout is generated. If IPRNT=1, a record of the printout is output in this step.

Step 17

If the attitude or ephemeris data are obtained from the Telemetry Data Base, there are either 4 or 128 time frames (a time frame is represented by one reference attitude and one ephemeris measurement) extracted from each record of the telemetry dataset. Steps 6 through 16 are repeated for each time frame.

Step 18

After all of the time frames generated from one telemetry record have been processed, steps 3 through 17 are repeated for each successive telemetry record.

Step 19

The final statistical computations are made and the summary report is generated. The summary report contains all of the model parameters, descriptive information about the simulation (e.g., time span covered), and the computed statistics.

6.2 INPUTS AND OUTPUTS

6.2.1 NAMELIST Inputs

The NAMELIST input file for the Scanner Measurement Predictor, &SMPIN, contains the following variables:

Control Parameters

ICOMP	Flag indicating type of comparison to be generated: ICOMP = 0 Observed vs. predicted = 1 Predicted vs. predicted = 2 Predicted vs. predicted with noise simulated in second set of measurements
IFIRST	First record of Telemetry input file to be read
LAST	Last record of Telemetry input file to be read
TSTART	Start time to read from Telemetry input file in format YYMMDD.HHMMSS
TEND	End time to read from Telemetry input file in format YYMMDD.HHMMSS
TSTEP	Time step for predicted vs. predicted mode comparisons
NP	Flag indicating number of predictions to be made when using timing information from the telemetry dataset: = 1 make 1 prediction per telemetry record. = 4 make 4 predictions per telemetry record. = 128 make 128 predictions per telemetry record.

Reference Attitude Parameters

IATT	Flag for source of reference attitudes: IATT = 0 OBC Attitudes from Telemetry Data Base = 1 Constant Pitch, Roll, Yaw

PITCH   Pitch angle for constant attitude

ROLL   Roll angle for constant attitude

YAW   Yaw angle for constant attitude

Ephemeris Parameters

IEPHEM   Ephemeris source flag:

IEPHEM = 0   Use Telemetry Data Base

= 1   Use ephemeris subroutine EPHEMX

ISPC   EPHEMX methods for obtaining spacecraft positon.

= 1   ORBGEN, use orbital elements from NAMELIST

= 2   DTAPRE (entry point of RO1TAP), read sequential EPHEM file

= 3   GETVCT/GETHDR read direct access orbit file

TEPOCH   Epoch time of orbital elements in format YYMMDD.HHMMSS

A   Semi-major axis (km)

E   Eccentricity

EYE   Inclination (degrees)

EMO   Mean anomaly (degrees)

WO   Argument of perigee (degrees)

RANODE   Right ascension of ascending node (degrees)

Scanner Alignment Parameters

AZIMO(2)   Scanner mounting alignment azimuth angle

TILTO(2)   Scanner mounting alignment tilt angle

TWISTO(2)   Scanner mounting alignment twist angle

DAZIM(2)   Misalignment in azimuth angle

DTILT(2)   Misalignment in tilt angle

DTWIST(2)   Misalignment in twist angle

CONEO(2)   Nominal scanner cone angle

DCONE(2)   Cone angle bias

Earth Modeling Parameters

ERAD	Earth equatorial radius
FLATCO	Earth flattening coefficient
DHIN	Degrees of scanner rotation inside the ideal Earth-in crossing used in the horizon crossing Earth latitude and longitude determination.
DHOUT	Degrees of scanner rotation inside the ideal Earth-out crossing used in the horizon crossing Earth latitude and longitude determination.

Horizon Radiance Correction Parameters

IHRCOR	Flag for horizon radiance corrections: IHRCOR = 0 Use Horizon Triggering Heights Data Base = 1 Use analytic expression = 2 Do not apply corrections
HORHGT	Nominal horizon radiance height for input to oblate Earth model
DHRHGT	Constant horizon radiance height bias
IVAR	Flag indicating independent variable in analytic expression: IVAR = 0 horizon crossing latitude = 1 orbit position (true anomaly from the ascending node)
MXFOUR	Maximum order of Fourier expansion (maximum of 7)
H	Zero-order coefficient in Fourier expansion
A	Sin-wave coefficients
B	Cos-wave coefficients
HRNOM	Nominal horizon radiance height for correction factor

Temperature Dependent Corrections

ITPCOR	Flag for temperature dependence corrections: ITPCOR = 0 Do not apply corrections = 1 Apply corrections
TNOM(2)	Nominal scanner temperature
BTNOM(2)	Nominal bolometer temperature
ETCOEF (3,2)	Coefficients in polynomial correction for scanner temperature dependence in E-voltage output
HTCOEF (3,2)	Coefficients in polynomial correction for scanner temperature dependence in H-voltage output
EBCOEF (3,2)	Coefficients in polynomial correction for bolometer temperature dependence in E-voltage output
HBCOEF (3,2)	Coefficients in polynomial correction for bolometer temperature dependence in H-voltage output

Constant Bias Parameters

DERAD(2)	Constant angular Earth radius bias
WIDTHO(2)	Nominal Earth width
PHASEO(2)	Nominal Earth phase
WCOEF(2)	Coefficients for constant bias and calibration polynomial correction to Earth width prediction
PCOEF(2)	Coefficients for constant bias and calibration polynomial correction to Earth phase prediction

Voltage Conversion Parameters

CONWID(2)	Conversion factor from Earth width to rotation angle E_T
CONPHA(2)	Conversion factor from Earth phase to rotation angle H_T
EVTOA(2)	E voltage-to-angle scale factor
HVTOA(2)	H voltage-to-angle scale factor

DPITCH(2)	Pitch offset voltage
DROLL(2)	Roll offset voltage
CTOV	Counts-to-volts scale factor
VTOST	Voltage to scanner temperature conversion factor
VTOBT	Voltage to bolometer temperature conversion factor

Noise Simulation Parameters

NPOINT	Number of points used in N-point average for noise simulation
STDE	Standard deviation of noise in E voltage
STDH	Standard deviation of noise in H voltage

Input/Output Control Parameters

ITLM	Logical unit number of telemetry input file
ITHDB	Logical unit number of Horizon Triggering Heights input file
IDBG	Logical unit number of debug output file
IMDB	Logical unit number of predictor output dataset
IHPP	Logical unit number of Horizon Positions Printout
IPRNT	Flag indicating whether or not to generate the Horizon Position Printout: IPRNT = 0 do not generate printout = 1 generate printout
IHPSFT	Skipping factor for Horizon Positions Printout (output every n^{th} time frame)
LEVDBG	Level of debug output to be generated: LEVDBG = 0 none = 10 minimal = 20 moderate = 30 maximum

6.2.2 Dataset Inputs

Telemetry Input

The telemetry dataset is selected from the Telemetry Data Base. See Section 2.1 for a description of its format.

Triggering Heights Input

The Triggering Heights Data Base is read if the option to apply horizon radiance corrections from it is selected. See Section 2.4 for a description of its content and format.

6.2.3 Dataset Outputs

The Scanner Measurement Predictor writes to a dataset that is entered in the Measurements Data Base. See Section 2.5 for a description of its content and format.

6.2.4 Printouts

Summary Report

The summary report contains the following information:

(1) NAMELIST Parameters
(2) Time span covered in the simulation
(3) Total number of measurements predicted
(4) Minimum, maximum, mean, root-mean-square, standard deviation of the residuals

(5) Maximum, minimum, and mean of each of the following variables:
- Earth width and phase (predicted and observed)
- Earth-in and Earth-out angles (predicted and observed)
- Bolometer and scanner temperatures

Horizon Positions Printout

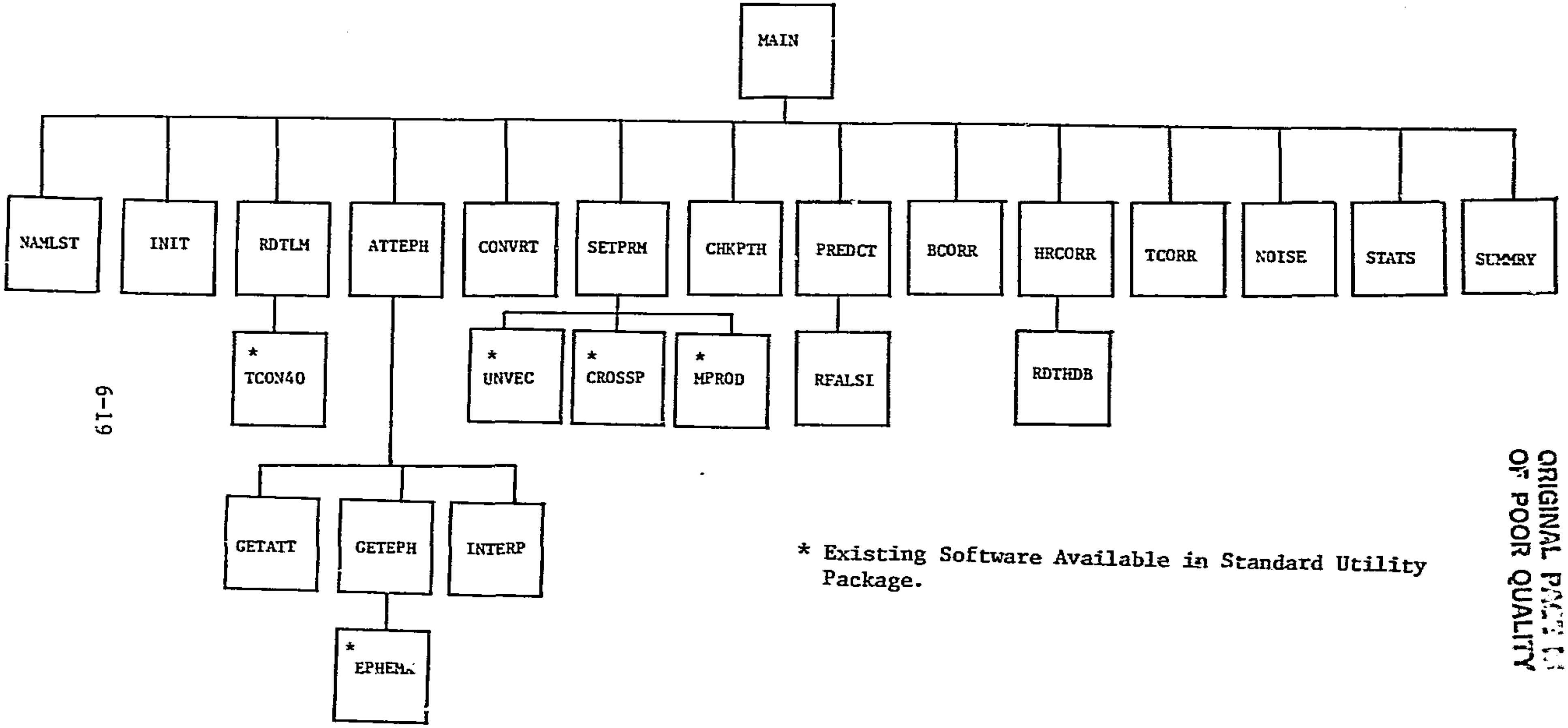
The Horizon Positions Printout displays the computed horizon crossing positons for each scanner as a function of time and orbit position. The horizon crossing positions (in-crossing and out-crossing) are expressed in terms of latitude and longitude. The orbit position is expressed in terms of subsatellite latitude and longitude. The time is in format YYMMDD.HHMMSS.

Debug Output File

The amount of information contained in the debug output file is determined by the NAMELIST parameter LEVDBG. The actual output associated with each level has not been defined.

6.3 SYSTEM STRUCTURE

Figure 6-2 shows the baseline diagram of the Scanner Measurement Predictor. The MAIN routine acts as the driver of the system and calls the remaining subroutines to perform most of the computation. Table 6-1 lists the functional steps described in Section 6.1 along with the names of the major subroutines that support them.



* Existing Software Available in Standard Utility Package.

Figure 6-2 Scanner Measurement Predictor Baseline Diagram

Table 6-1 Relationship Between Functional Steps and Subroutines

Step	Subroutines
1	NAMLST
2	INIT
3	RDTLM
4	ATTEPH
5	CONVRT
6	SETPRM
7	CHKPTH
8	PREDCT
9	BCORR
10	HRCORR
11	TCORR
12	MAIN
13	MAIN
14	NOISE
15	STATS
16	MAIN
17	MAIN
18	MAIN
19	STATS,SUMMRY

6.4 SUBROUTINE DESCRIPTIONS

Each subroutine of the Scanner Measurement Predictor subsystem is described below in terms of its purpose, procedure, input parameters, and output parameters. Descriptions of existing software (e.g. TCON40, UNVEC) are omitted.

MAIN

Purpose: MAIN is the driver of the Scanner Measurement Predictor.

Procedure:

(1) Call NAMLST to input model parameters.

(2) Call INIT to initialize orbit-level parameters that do not change throughout the simulation.

(3) If IATT=0 or IEPHEM=0 or ICOMP=0, call RDTLM to read a record of the telemetry dataset.

(4) Call ATTEPH to initialize attitude and ephemeris dependent parameters.

(5) If ICOMP=0 or ITPCOR=1, call CONVRT to convert scanner measurements from counts to angles and ^{o}C.

(6) Call SETPRM to initialize scanner dependent parameters.

(7) Call CHKPTH to determine whether or not the scan path crosses the horizon. If not, insert a flag for the predicted measurements and omit steps 8 through 11.

(8) Call PREDCT to calculate Earth width and phase, WIDTHP and PHASEP.

(9) Call BCORR to apply constant bias corrections to WIDTHP and PHASEP.

(10) If IHRCOR=1, call HRCORR to apply horizon radiance variance corrections to WIDTHP and PHASEP.

(11) If ITPCOR=1, call TCORR to apply temperature dependent corrections to WIDTHP and PHASEP.

(12) Loop through steps 6 to 11 for each scanner.

(13) If ICOMP=0, repeat steps 6 to 12 to obtain second set of predicted measurements.

(14) If ICOMP=2, call NOISE to simulate noise in second set of predicted measurements.

(15) Call STATS to compute residuals and to update statistical computations.

(16) Write record to output dataset (Measurements Data Base). See Section 2.5.2 for a description of the record contents. If Horizon Positions Printout is requested, write out a record.

(17) After all requested data has been processed, generate summary report.

(18) Throughout the above steps, MAIN performs error checking and writes debug output messages if requested.

Input Parameters: None

Output Parameters: None

NAMLST

Purpose: NAMLST reads in the model parameters from the NAMELIST input file &SMPIN.

Procedure:

(1) Perform NAMELIST read.

(2) Test for read errors and set error flags if any occurs.

Input Parameters: None

Output Parameters:

IERR Error flag:
IERR=0 no error
=1 read error occurred

The remaining output parameters are listed by common block:

/CTRL/

ICOMP Comparison type flag:
ICOMP = 0 Predicted vs. Observed
= 1 Predicted vs. Predicted
= 2 Predicted vs. Predicted (Noisy)

NP Flag indicating number of predictions per major frame:
NP = 1 1 prediction per major frame
= 128 128 predictions per major frame
= 4 4 predictions per major frame

TSTEP Time step to be used when telemetry timing data is not used.

/TLMCTL/

IFIRST	First record of Telemetry input file to be read
LAST	Last record of Telemetry input file to be read
TSTART	Start time to read from Telemetry input file in format YYMMDD.HHMMSS
TEND	End time to read from Telemetry input file in format YYMMDD.HHMMSS

/ATTIT/

IEPHEM	Flag indicating source of ephemeris: IEPHEM = 0 Telemetry data base = 1 EPHEMX ephemeris model
IATT	Flag for source of reference attitudes: IATT = 0 OBC Attitudes from telemetry data base = 1 Constant Pitch, Roll, Yaw
PITCH	Pitch angle for constant attitude
ROLL	Roll angle for constant attitude
YAW	Yaw angle for constant attitude

/PARAMS/

AZIMO	Scanner mounting alignment azimuth angle
TILTO	Scanner mounting alignment tilt angle
TWISTO	Scanner mounting alignment twist angle
DAZIM	Misalignment in azimuth angle
DTILT	Misalignment in tilt angle
DTWIST	Misalignment in twist angle
CONEO	Normal scanner cone angle
DCONE	Cone angle bias
ERAD	Earth equatorial radius

FLATNO	Earth flattening coefficient
HORHGT	Nominal horizon radiance height (input to oblate Earth model)
DHIN	Earth-in horizon crossing position determination adjustment.
DHOUT	Earth-out horizon crossing position determination adjustment.

/HRCORR/

IHRCOR	Flag for horizon radiance corrections: IHRCOR = 0 Use Horizon Triggering Heights Data Base = 1 Use analytic expression = 2 Do not apply corrections
HRNOM	Nominal horizon radiance height
MXFOUR	Maximum order of Fourier expansion
H	Zero-order coefficient in Fourier expansion
A	Sin-wave coefficients
B	Cos-wave coefficients
DHRHGT	Constant horizon radiance height bias
IVAR	Independent variable selection flag

/TCORR/

ITPCOR	Flag for temperature dependence corrections: ITPCOR = 0 Do not apply corrections = 1 Use scanner and bolometer temperatures for corrections
TNOM	Nominal scanner temperature
BTNOM	Nominal bolometer temperature
ETCOFF	Coefficients in polynomial correction for scanner temperature dependence in E-voltage output

HTCOEF	Coefficients in polynomial correction for scanner temperature dependence in H-voltage output
EBCOEF	Coefficients in polynomial correction for bolometer temperature dependence in E-voltage output
HBCOEF	Coefficients in polynominal correction for bolometer temperature dependence in H-voltage output

/BIASES/

DERAD	Constant angular Earth radius bias
WIDTHO	Nominal Earth width
PHASEO	Nominal Earth phase
WCOEF	Coefficients for polynomial correction to Earth width
PCOEF	Coefficients for polynomial correction to Earth phase

/CONVRT/

CONWID	Conversion factor from Earth width to rotation angle E_T
CONPHA	Conversion factor from Earth phase to rotation angle H_T
EVTOA	E voltage-to-angle scale factor
HVTOA	H voltage-to-angle scale factor
DPITCH	Pitch offset voltage
DROLL	Roll offset voltage
CTOV	Counts-to-volts scale factor

/NOISE/

NPOINT	Number of points used in N-point average for noise simulation
STDE	Standard deviation of noise in E voltage
STDH	Standard deviation of noise in H voltage

/LUNITS/

ITLM	Logical unit number of telemetry input file
THDB	Logical unit number of Horizon Triggering Heights input file
IMDB	Logical unit number of predictor output dataset
IHPP	Logical unit number of Horizon Positions Printout
IPRNT	Horizon Positions Printout on/off flag

/DEBUG/

IDBG	Logical unit number of debug output file
LEVDBG	Level of debug output to be generated

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INIT

Purpose: INIT initializes orbit-dependent parameters that do not change throughout the simulation.

Procedure:

(1) Compute scanner mounting alignment angles:

```
AZIM(I) = AZIMO(I) + DAZIM(I)
TILT(I) = TILTO(I) + DTILT(I)
TWIST(I) = TWISTO(I) + DTWIST(I)
CONE(I) = CONEO(I) + DCONE(I)
for I = 1, 2
```

(2) Compute scanner mounting alignment matrix:

```
SMOUNT(1,1,I) = cos(TILT(I))*cos(AZIM(I))
SMOUNT(2,1,I) = -cos(TWIST(I))*sin(AZIM(I))
                + (TILT(I))*cos(AZIM(I))
SMOUNT(3,1,I) = sin(TWIST(I))*sin(AZIM(I))
                + cos(TWIST(I))*sin(TWIST(I))*cos(AZIM(I))
SMOUNT(1,2,I) = cos(TWIST(I))*sin(AZIM(I))
SMOUNT(2,2,I) = cos(TWIST(I))*cos(AZIM(I))
                + sin(TWIST(I))*sin(TILT(I))*sin(AZIM(I))
SMOUNT(3,2,I) = -sin(TWIST(I))*cos(AZIM(I))
                + cos(TWIST(I))*sin(TILT(I))*sin(AZIM(I))
SMOUNT(1,3,I) = -sin(TILT(I))
SMOUNT(2,3,I) = sin(TWIST(I))*cos(TILT(I))
SMOUNT(3,3,I) = cos(TWIST(I))*cos(TILT(I))
for I = 1,2
```

Input Parameters:

ICOMP	Comparison type flag

The remaining input parameters are from common block /PARAMS/.

Output Parameters:

AZIM	Scanner mounting alignment azimuth angle
TILT	Scanner mounting alignment tilt angle
TWIST	Scanner mounting alignment twist angle
CONE	Scan cone radial arc-length from scanner spin axis
SMOUNT	Scanner mounting alignment matrix

RDTLM

Purpose: RDTLM reads a record of the telemetry input dataset. If IFIRST or TSTART is set, RDTLM positions the dataset at the appropriate record by performing sequential reads.

Procedure:

(1) If IFIRST is greater than 1, perform sequential reads to position the dataset at record number IFIRST.
(2) If ISTART is greater than 0, perform sequential reads until the time value from the record is greater than or equal to TSTART.
(3) Read in the telemetry record.
(4) Check for end-of-file conditions:
    a) Physical EOF
    b) Current record greater than LAST
    c) Time on current record greater than TLAST
(5) Check for read errors.

Input Parameters:

ITLM	Logical unit number of the telemetry dataset
IREC	Number of the record currently being processed
TCURR	Time value of the record currently being processed

The following input parameters are from common block /TLMCTL/:

IFIRST	First record of Telemetry input file to be read
LAST	Last record of Telemetry input file to be read
TSTART	Start time to read from Telemetry Input file in format YYMMDD.HHMMSS

TEND End time to read from Telemetry input file in format YYMMSS.HHMMSS

Output Parameters:

IERR End-of-file and error flag:

IERR = 0 successful read

= 1 end-of-file

= 2 read error

IREC, TCURR are updated if successful read occurred

The remaining output parameters are listed by common block:

/CSDATA/

IROLLF Observed roll measurements in counts

IPITF Observed pitch measurements in counts

ISIGNL Signal status flags

ITEMP Observed scanner temperatures in counts

IBOLO Observed bolometer temperatures in counts

ISENSR Sensor status flags

MODES Mode flags indicating various operational conditions

/TIMING/

TIME Time on each record in seconds since Sept. 1, 1957.

/ATTEPH/

EPARMS Euler parameters representing OBC reference attitudes

EPHPOS Spacecraft position in GCI coordinates

EPHVEL Spacecraft velocity in GCI coordinates

ATTEPH

Purpose: ATTEPH obtains the attitude and ephemeris data for a set of time frames. The number of time frames that are initialized on each call to ATTEPH depends on the NAMELIST parameters ICOMP and NP.

Procedure:

(1) Call GETATT to obtain the reference attitudes. If NP=128, and IATT=0, call INTERP to interpolate the measurements returned from GETATT.
(2) Call GETEPH to obtain the ephemeris. If NP=128 and IEPHEM=0, call INTERP to interpolate the measurements.
(3) Perform error checking.

Input Parameters:

IATT	Flag indicating attitude source
IEPHEM	Flag indicating ephemeris source
NP	Flag indicating number of time frames initialized
TCURR	Current time

The remaining input parameters are listed by common block:

/ATTEPH/

EPARMS	Euler parameters representing OBC reference attitudes
EPHPOS	Spacecraft position in GCI coordinates
EPHVEL	Spacecraft velocity in GCI coordinates

/DEBUG/

IDBG	Logical unit number of debug output file
LEVDBG	Level of debug output to be generated

Output Parameters:

XPITCH	Pitch measurements
XROLL	Roll measurements
XYAW	Yaw measurements
SCPOS	Spacecraft position vectors
SCVEL	Spacecraft velocity vectors
IERR	Error flag:
	IERR = 0 no error
	= 1 error occurred

GETATT

Purpose: GETATT obtains reference attitude in the form of pitch, roll, yaw from the OBC Euler parameters.

Procedures:

(1) Compute the attitude matrix from the Euler parameters.

(2) Obtain pitch, roll, and yaw from the attitude matrix.

Input Parameters:

EPARMS	Euler parameters representing OBC reference attitudes

Output Parameters:

PITCH	Pitch measurements
ROLL	Roll measurements
YAW	Yaw measurements

GETEPH

Purpose: GETEPH obtains the ephemeris in the form of spacecraft position and velocity vectors in GCI coordinates.

Procedures:

(1) If IEPHEM = 1, call EPHEMX to obtain position and velocity vectors.

(2) If IEPHEM = 0, use ephemeris from telemetry.

Input Parameters:

IEPHEM	Ephemeris source flag
NP	Number of ephemeris points to be retrieved (1 or 4)
EPHVEL	Spacecraft velocity vector from Telemetry Data Base
EPHPOS	Spacecraft position vector from Telemetry Data Base
CURTIM	Current time
TIMSTP	Time increment

Output Parameters:

E	Spacecraft to Earth center vector
V	Spacecraft velocity vector

CONVRT

Purpose: CONVRT converts the observed pitch and roll measurements from telemetry counts to angular Earth width and phase, and converts the observed temperatures from telemetry counts to degrees centigrade.

Procedures:

(1) Convert voltages to angular Earth width and phase:

```
WIDTH(I,J)=1/CONWID*(1/EVTOA*(VPITCH(I,J)-DPITCH)) + WIDTHO
PHASE(I,J)=1/CONPHA*(1/HVTOA*(VROLL(I,J)-DROLL)) + PITCH
for I = 1,128; J = 1,2.
```

(2) Compute Earth-in and Earth-out angles:

```
AIN = WIDTH/2 + PHASE
AOUT = -WIDTH/2 + PHASE
```

(3) Convert scanner and bolometer temperatures:

```
TEMP(I) = ITEMP(I,J)/CTOV * TVTOD
BOLO(I) = IBOLO(I,J)/CTOV * BVTOD
for I = 1,128; J = 1,2.
```

Input Parameters:

IFLAG Flag indicating conversions to be performed:

IFLAG = 0 all

= 1 temperature only

The remaining input parameters are listed by common blocks:

/CONVRT/

CONWID	Conversion factor from Earth width to rotation angle E_T
CONPHA	Conversion factor from Earth phase to rotation angle H_T
EVTOA	E voltage-to-angle scale factor
HVTOA	H voltage-to-angle scale factor
DPITCH	Pitch offset voltage
DROLL	Roll offset voltage
CTOV	Counts-to-volts scale factor

/CSDATA/

IROLLF	Observed roll measurements in counts
IPITF	Observed pitch measurements in counts
ISIGNL	Signal status flags
ITEMP	Observed scanner temperature in counts
IBOLO	Observed temperature in counts
ISENSR	Sensor status flags
MODES	Model flags indicating various operational conditions

Output Parameters:

WIDTH	Observed Earth width measurements
PHASE	Observed Earth phase measurements
AIN	Observed Earth-in angle
AOUT	Observed Earth-out angle
TEMP	Observed scanner temperature (deg C)
BOLO	Observed bolometer temperature (deg C)

SETPRM

Purpose: SETPRM initializes parameters that are dependent on each time-frame and scanner.

Procedures:

(1) Compute orbit normal direction.

(2) Compute GCI to orbital coordinates transformation matrix.

(3) Compute GCI to S/C coordinates transformation matrix.

(4) Compute scanner to Earth center direction.

(5) Compute arc-length separation between scanner spin axis and Earth vector.

(6) Compute latitude of subsatellite point.

(7) Compute Earth radius at subsatellite point.

(8) Compute Earth angular radius as seen from S/C.

(9) Compute scanner spin axis.

Input Parameters:

V	Spacecraft velocity vector
E	Spacecraft to Earth center vector
ATT	Attitude matrix
SMOUNT	Scanner mounting alignment matrix
ERAD	Earth equatorial radius
FLATCO	Earth flattening coefficient
HORHGT	Nominal horizon radiance height

Output Parameters:

ORBNRM	Orbit normal direction
GCIORB	GCI to orbital coordinates transformaion matrix
GCISC	GCI to spacecraft body coordinates transformation matrix

ES	Scanner to Earth center direction
ETA	Arc-length separation between scanner spin axis and Earth vector
SUBLAT	Subsatellite latitude
RSUB	Earth radius at subsatellite point
RHO	Earth angular radius
SPINAX	Scanner spin axis

CHKPTH

Purpose: CHKPTH determines whether or not the scan path crosses the Earth horizon.

Procedure:

(1) Determine whether scan path intersects the Earth for at least part of the scan:
ABS(ETA - CONE) ≤ RHO

(2) If condition (1) is met, determine whether scan path crosses the horizon:

(a) If ETA + CONE ≤ 180, then
ETA < CONE + RHO

(b) If ETA + CONE > 180, then
ETA + CONE < 360 - RHO

(3) If conditions (1) and (2) are met, set IPATH = 1. Otherwise set IPATH = 0.

Input Parameters:

ETA	Arc-length separation between scanner spin axis and Earth vector
CONE	Scan cone radial arc-length from scanner spin axis
RHO	Earth angular radius as seen from the S/C.

Output Parameters:

IPATH	Flag indicating whether or not scan path crosses horizon: IPATH = 0 path does not cross = 1 path crosses

PREDCT

Purpose: PREDCT computes the predicted Earth width and phase measurements assuming an oblate model of the Earth.

Procedure:

(1) Compute initial approximation to Earth width and phase:

```
WO=2*ACOS((COS(RHO)-COS(ETA)COS(CONE))/(SIN(ETA)*SIN(CONE)))
PO=ATAN2(-ES(2),ES(3))
```

(2) Call RFALSI to iteratively compute Earth-in angle AIN with AINO = WO/2 + PO, and AIN1 based on sign and value of AINO.

(3) Call RFALSI to iteratively compute the Earth-out angle, AOUT with AOUTO = -W/2 +PO, and AOUT1 based on sign and value of AOUTO.

(4) Compute final predictions of Earth width and phase by

```
WIDTHP = AOUT - AIN
PHASEP = (AIN + AOUT)/2
```

Input Parameters:

RHO	Earth angular radius
ETA	Arc-length separation between scanner spin axis and Earth vector
CONE	Scan cone radial arc-length
ES	Scanner to Earth vector
E	Earth vector
ERAD	Earth equatorial radius
SMOUNT	Scanner mounting alignment matrix
GCISC	GCI to spacecraft coordinates transformation matrix
EPS	Tolerance for convergence interval
HORHGT	Nominal horizon radiance height

Output Parameters:

WIDTHP	Earth width estimate
PHASEP	Earth phase estimate
AIN	Earth-in angle
AOUT	Earth-out angle
IERR	Error flag:
	IERR = 0 no error
	= 1 no convergence

BCORR

Purpose: BCORR applies constant bias parameters to the initial Earth width and phase measurements.

Procedure:

(1) Apply constant angular Earth radius adjustment:

```
WIDTHP = WIDTHP + (DWDR * DERAD)
PHASEP = PHASEP + (DPDR * DERAD)
```

Where DWDR and DPDR are the partial derivatives of width and phase with respect to the angular Earth radius.

(2) Apply polynomial correction:

```
WIDTHP = WIDTHP + (WCOEF(1) + WCOEF(2) * (WIDTHP - WIDTHO)
        + WCOEF(3) * (WIDTHP - WIDTHO) **2
        + WCOEF(4) * (PHASEP - PHASEO)
        + WCOEF(5) * (PHASFP - PHASEO) **2)
PHASEP = PHASEP + (PCOEF(1) + PCOEF(2) * (PHASEP - PHASEO)
        + PCOEF(3) * (PHASEP - PHASEO) **2
        + PCOEF(4) * (WIDTHP - WIDTHO)
        + PCOEF(5) * WIDTHP - WIDTHO) **2
```

Input Parmeters:

WIDTHP	Earth width estimate
PHASEP	Earth phase estimiate
DERAD	Earth radius constant bias
WIDTHO	Nominal Earth width
PHASEO	Nominal Earth phase
WCOEF	Earth width polynomial correction coefficients
PCOEF	Earth phase polynomial correction coefficients

Output Parameters:

WIDTHP	Earth width estimate
PHASEP	Earth phase estimate

RFALSI

Purpose: RFALSI iteratively computes the solution of a nonlinear equation using the Regula Falsi method.

Procedure:

(1) Compute (n+1)st point by
XNP1 = XN - FN * ((XN-XNM1)/(FN-FNM1))
where FN * FNM1 < 0.

(2) Perform convergence test:
ABS(FNP1) ≤ EPS

(3) If no convergence, iterate with
XNM1 = XN
XN = XNP1
FNM1 = FN
FN = FNP1

Input Parameters:

XO,X1	Initial points
F	External function for calculation of the equation at each X.
EPS	Convergence tolerance

Output Parameters:

X	Root of the equation within the given tolerance
IERR	Error flag: IERR = 0 no error = 1 no convergence

HRCORR

Purpose: HRCORR applies corrections for scanner responses to variations in Earth horizon radiance to the Earth width and phase estimates.

Procedure:

(1) If IHRCOR = 0, call RDTHDB to obtain the correction factor DHT.

(2) If IHRCOR = 1, evaluate analytic expression to obtain correction factor DHT

(3) Apply constant bias correction factor DHRHGT.

Input Parameters:

IHRCOR	Horizon radiance correction flag
DHRHGT	Constant bias horizon radiance height
MXFOUR	Order of Fourier expansion
H	Zero-th order term
A	Sin-wave coefficients
B	Cos-wave coefficients
HRNOM	Nominal horizon radiance height
WIDTHP	Earth width estimate
PHASEP	Earth phase estimate
IVAR	Independent variable selection flag

Output Parameters:

WIDTHP	Earth width estimate
PHASEP	Earth phase estimate
IERR	Error flag
	IERR = 0 no error
	= 1 error in reading THDB

TCORR

Purpose: TCORR adjusts the Earth width and phase estimates to account for temperature dependent effects.

Procedure:

(1) Compute scanner temperature correction factor for Earth width:

WIDTHP = WIDTHP + [ETCOEF(1) + ETCOEF(2) * (TEMP - TNOM)
+ ETCOEF(3) * (TEMP - TNOM) **2]

(2) Compute scanner temperature correction factor for Earth phase:

PHASEP = PHASEP + [HTCOEF(1) + HTCOEF(2) * (TEMP - TNOM)
+ HTOCEF(3) * (TEMP - TNOM) **2]

(3) Compute bolometer temperature correction for Earth width:

WIDTHP = WIDTHP + [EBCOEF(1) + EBCOEF(2) * (BOLO - BTNOM)
+ EBCOEF(3) * (BOLO - BTNOM) **2]

(4) Compute bolometer temperature correction for Earth phase:

PHASEP = PHASEP + [HBCOEF(1) + HBCOEF(2) * (BOLO - BTNOM)
+ HBCOEF(3) * (BOLO - BTNOM) **2]

Input Parameters:

WIDTHP	Earth Width estimate
PHASEP	Earth Phase estimate
TEMP	Observed Scanner temperature
TNOM	Nominal Scanner temperature
BOLO	Observed bolometer temperature
BTNOM	Nominal bolometer temperature
ETCOEF	Coefficients for scanner temperature correction to Earth Width
HTCOEF	Coefficients for scanner temperature correction to Earth Phase

EBCOEF	Coefficients for bolometer temperature correction to Earth Width
HBCOEF	Coefficients for bolometer temperature correction to Earth Phase

Output Parameters:

WIDTHP	Earth Width estimate
PHASEP	Earth Phase estimate

STATS

Purpose: Compute basic statistics (minimum, maximum, mean, root-mean-square, standard deviation) of Earth width and phase measurements, Earth-in and Earth-out angles, residuals, temperatures.

Procedures:

(1) If IFLAG = 0, then compute residuals, update running sums, and update maxima and minima.

(2) If IFLAG = 1, then compute final statistics.

Input Parameters:

IFLAG	Flag indicating termination of data. IFLAG = 0 update sums, etc. = 1 compute final statistics
WIDTHP	Earth Width estimate
PHASEP	Earth Phase estimate
AINP	Earth-in angle estimate
AOUTP	Earth-out angle estimate
WIDTH	Observed Earth Width
PHASE	Observed Earth Phase
AIN	Observed Earth-in Angle
AOUT	Observed Earth-out Angle
TEMP	Observed Scanner temperature
BOLO	Observed Bolometer temperature

Output Parameters:

XMIN	Minima of above variables
XMAX	Maxima of above variables
XMEAN	Means of above variables
RMS	Root-mean-squares of residual errors
STDR	Standard deviations of residual errors
RMIN	Minima of residual errors
RMAX	Maxima of residual errors
RMEAN	Means of residual errors
N	Total number of points

NOISE

Purpose: NOISE adjusts the computed Earth width and phase estimates to simulate random noise.

Procedure:

(1) Call RAVNZ1 to compute noise factor for Earth width estimate for scanner 1.

(2) Call RAVNZ2 to compute noise factor for Earth width estimate for scanner 2.

(3) Call RAVNZ3 to compute noise factor for Earth phase estimate for scanner 1.

(4) Call RAVNZ4 to compute noise factor for Earth phase estimate for scanner 2.

Input Parameters:

WIDTHP	Earth Width estimate
PHASEP	Earth Phase estimate
STDE	Standard deviation of noise in E voltage
STDH	Standard deviation of noise in H voltage
NPOINT	Number of points in running average

Output Parameters:

WIDTHP	Earth Width estimate
PHASEP	Earth Phase estimate

SUMMRY

Purpose: SUMMRY generates a report of the prediction including basic statistics of various data.

Procedure:

Output each of the following:

(1) Heading and date

(2) NAMELIST parameters

(3) Initial/final times

(4) Total number of measurements

(5) Basic statistics

Input Parameters:

TINIT	Initial time
TFINAL	Final time
XMIN	Minima of observed and computed measurements
XMAX	Maxima of observed and computed measurements
XMEAN	Means of observed and computed measurements
RMS	Root-mean-squares of residual errors
STDR	Standard deviations of residual errors
RMIN	Minima of residual errors
RMAX	Maxima of residual errors
RMEAN	Means of residual errors
N	Total number of points

The remaining input parameters are from common blocks CTRL, TLMCTL, ATTIT, PARAMS, HRCORR, TCORR, BIASES, CONVRT, NOISE, LUNITS, DEBUG. See subroutine NAMLST for common block contents.

Output Parameters: NONE

SECTION 7 - DATA PLOTTING AND FITTING UTILITY

7.1 FUNCTIONAL DESCRIPTION

The functions of the Data Plotting and Fitting Utility (DPFU) are to produce Calcomp plots of selected variables from the Measurements Data Base and optionally compute fits to the variables. Plots may be stacked or overlayed as desired. To make the DPFU flexible and convenient to use, most of the important plot parameters are determined by options specified in the NAMELIST input file. Among the options is the ability to choose the variables that are to be plotted. While there are few inherent restrictions on which variables can be plotted against each other, some typical selections include

- predicted measurement vs. time
- observed measurement vs. time
- residuals vs. time
- residuals vs. spacecraft orbit positon
- residuals vs. scanner or bolometer temperature
- residuals vs. horizon crossing latitude
- triggering heights vs. horizon crossings latitude

Other plot parameters that are set by NAMELIST options are plot scales, axis labels, plot title, and number of plots to be stacked or overlayed. In addition, the plot can be drawn with or without a data-fitting line.

The following data fitting procedures are available:

1. Polynomial fit
2. Finite Fourier Series Fit

Also, the system allows a combination of polynomial and finite Fourier series terms to be fit.

While typical use of the fitting procedures is to plot the fitting line, there is an option to suppress the plot and just print the coefficients of the fit in the Summary Report. It is also possible to plot a "fit" that is input from the NAMELIST and not computed from the selected data span.

By default, the DPFU computes the mean of each variable and displays it on the plot. This feature can be suppressed if desired.

If the option to stack or overlay a series of plots is selected, each plot is defined by a separate NAMELIST file. The DPFU interates through the NAMELIST files until all of the plots are drawn.

7.2 INPUTS AND OUTPUTS

7.2.1 NAMELIST Input

The Data Plotting and Fitting Utility reads the following parameters from the NAMELIST input file, &DPFUIN:

IOPT	Plot option flag:	
	IOPT = 0	No Plot
	= 1	Standard Plot
	= 2	Serial Stacked Plot
	= 3	Parallel Stacked Plot
	= 4	Overlay Plot
NPLOTS	Number of plots (for IOPT = 2,3,4)	
IFIT	Data-fitting option:	
	IFIT = 0	no fitting
	= 1	perform fit and plot fit
	= 2	perform fit
	= 3	use input fit coefficients
NAVG	Number of points to be used in data averaging	
ISIFT	Data sift factor for plot and data-fitting procedure	
ICONST, IDEG(5), ISIN(7), ICOS(7)	Arrays indicating selection of basis functions for data-fitting procedure.	
PERIOD	Basic period for finite Fourier series fit	
CCONST, CDEG(5), CSIN(7), CCOS(7)	Input fit coefficients for optional plot of "fit" for NAMELIST input coefficients.	
XPOINT	Cut-off point on x-axis for series plot (IOPT = 2)	

IXVAR
IYVAR } X and Y axis variable indicators, where

1	Observed Earth Width
2	Observed Earth Phase
3	Observed Earth-in angle
4	Observed Earth-out angle
5	Predicted Earth width
6	Predicted Earth Phase
7	Predicted Earth-in angle
8	Predicted Earth-out angle
9	Residual Earth Width error
10	Residual Earth Phase error
11	Residual Earth-in angle error
12	Residual Earth-out angle error
13	Residual Pitch error
14	Residual Roll error
15	Earth-in triggering height
16	Earth-out triggering height
17	Bolometer temperature
18	Scanner temperature
19	Signal Status
20	Sensor Status
21	Predicted Earth-in horizon crossing latitude
22	Predicted Earth-out horizon crossing latitude
23	Reference Pitch
24	Reference Roll
25	Reference Yaw
26	Spacecraft altitude
27	Subsatellite latitude
28	Subsatellite longitude

	29	Satellite orbit phase angle relative to ascending node
	30	Time
ISCAN	Scanner number (1 or 2)	
MAXN	Maximum number of points to be plotted	
ICHAR	Plot character, If ICHAR is not specified then a solid line is drawn.	
XLEN	Length of x-axis in inches	
YLEN	Length of y-axis in inches	
XMIN	Minimum x-axis value	
XMAX	Maximum x-axis value	
YMIN	Minimum y-axis value	
YMAX	Maximum y-axis value	
TSTEP	Time step for tic marks on x-axis when x-variable is TIME (in seconds)	
TSCALE	Scale on x-axis when x-variable is TIME (in sec/inch)	
TITLE	Plot title	
XTITLE	x-axis title	
YTITLE	y-axis title	

7.2.2 Dataset Input

The dataset input to the Data Plotting and Fitting Utility is from the Measurements Data Base. For a description of its format and content, see Section 2.5.

7.2.3 Plot Output

The Calcomp plot utilities write to an output file which is stored on tape. The tape is then carried to the Calcomp plot facilities to obtain the hardcopy plot output. Figures 7-1 through 7-4 are representative of the kinds of plots generated by the DPFU.

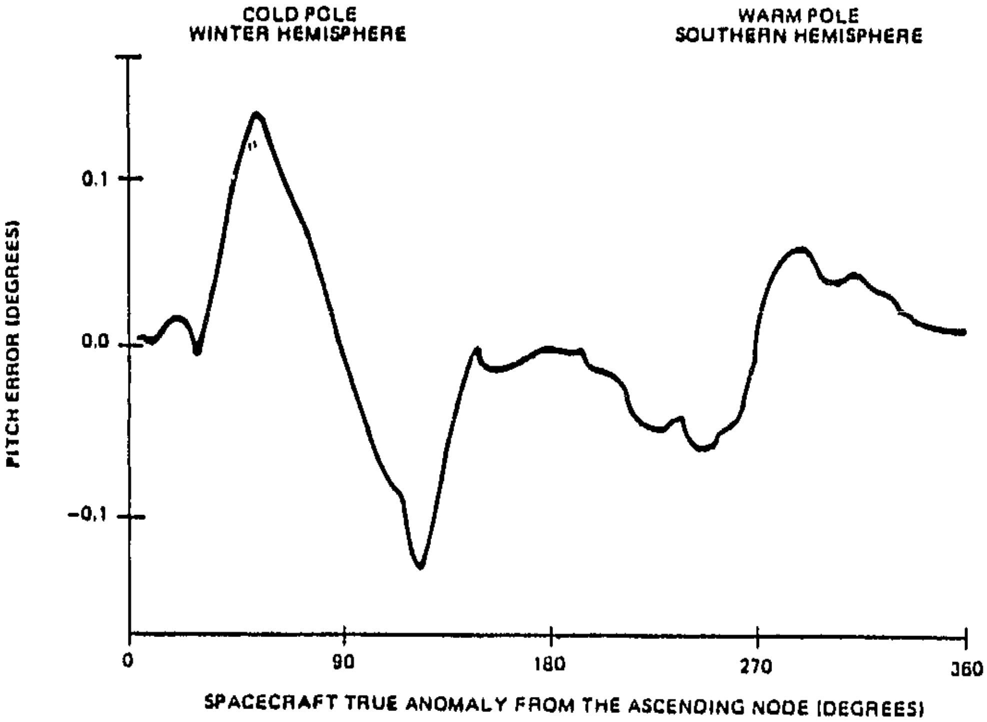

Figure 7-1 Standard Plot

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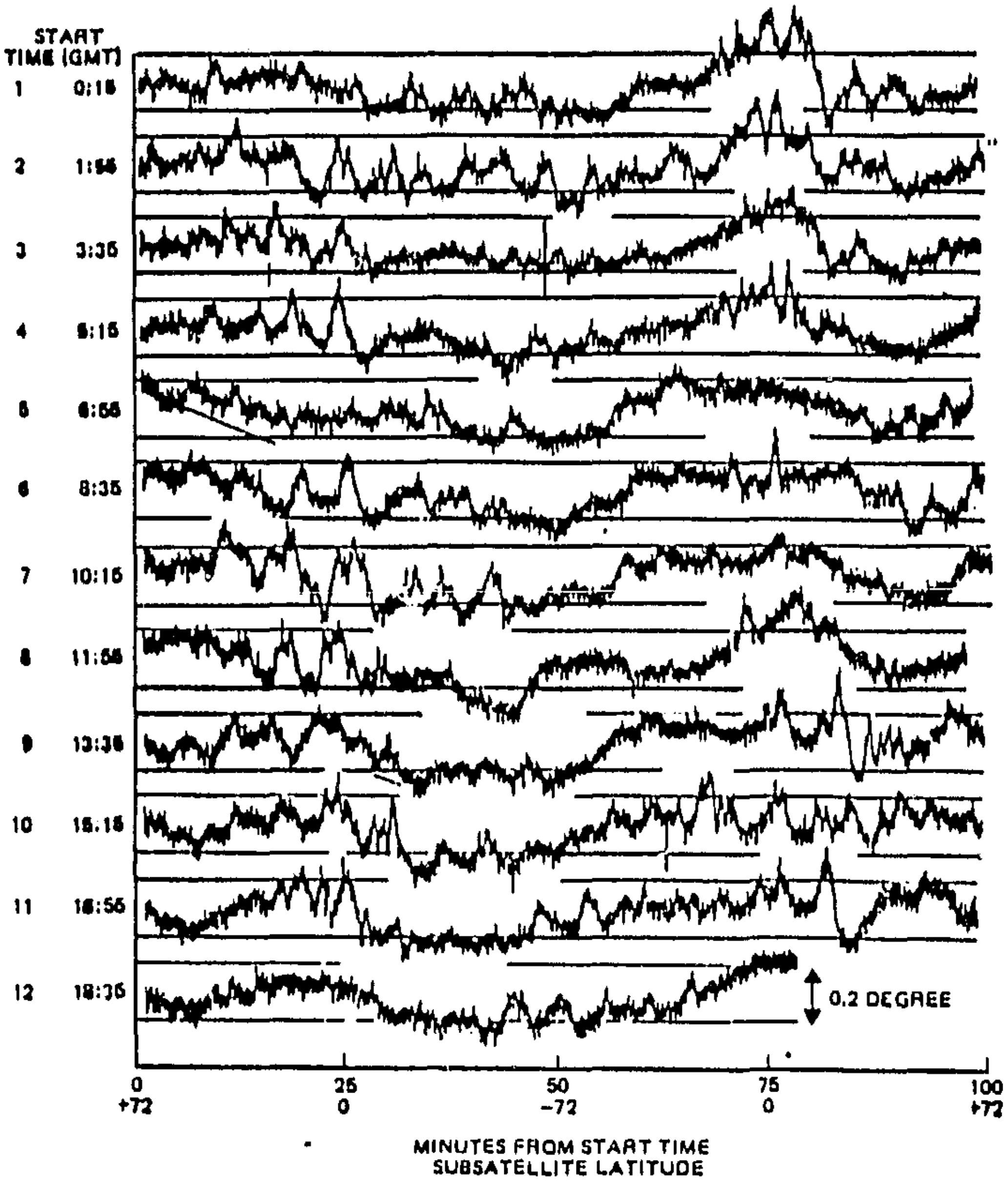

Figure 7-2 Serial Stacked Plot

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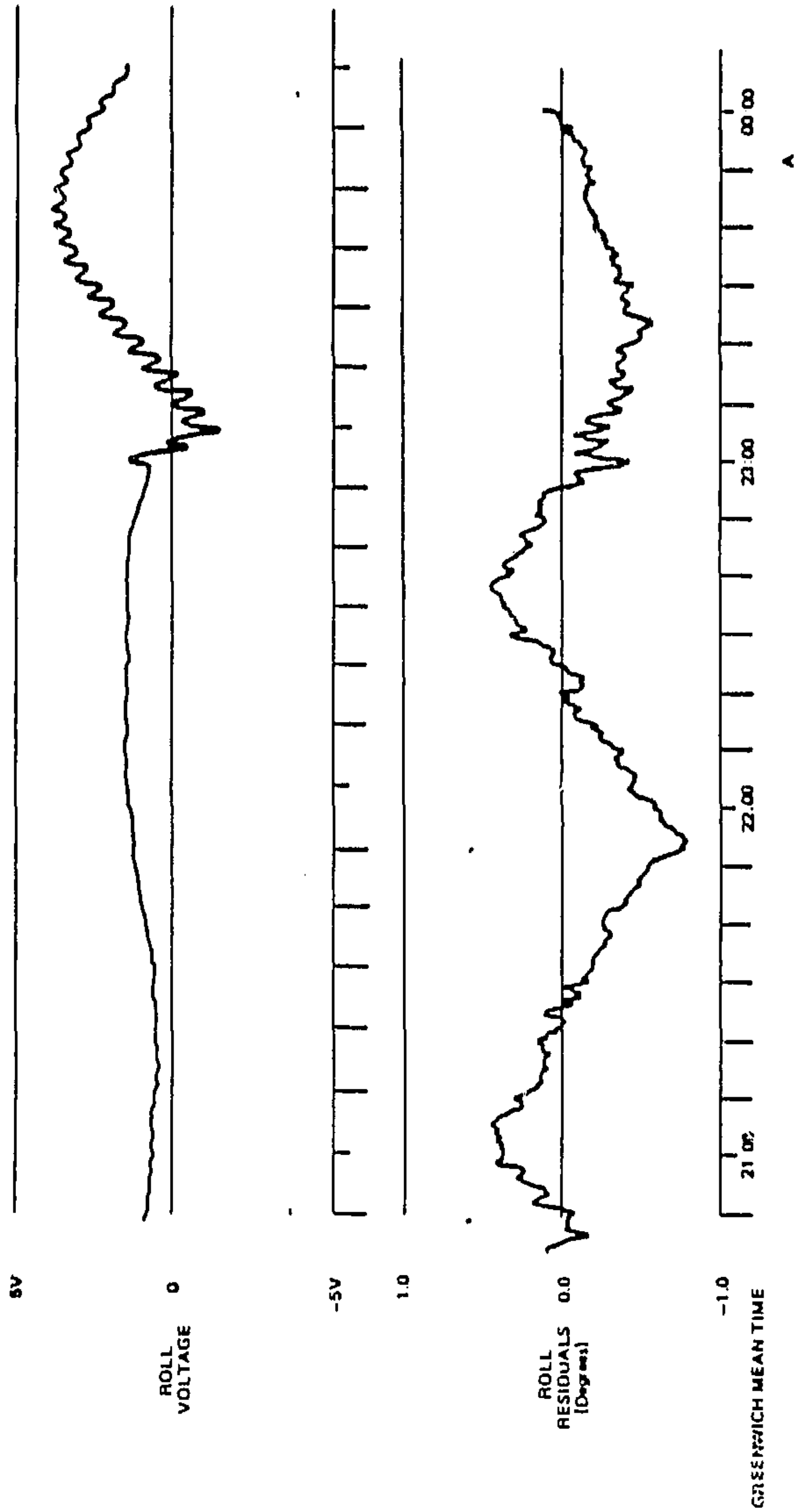

Figure 7-3 Parallel Stacked Plot

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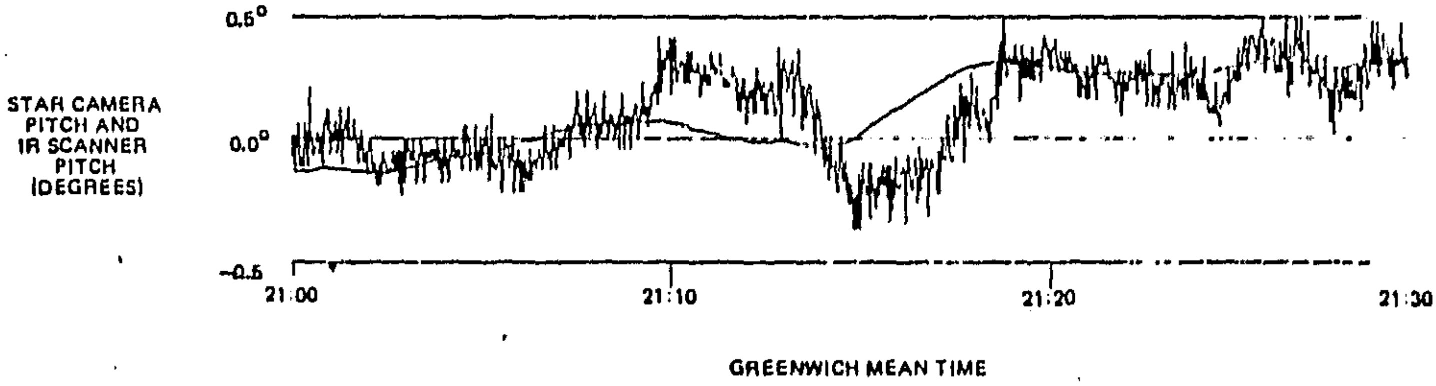


Figure 7-4 Overlayed Plot

7.2.4 Printout

Summary Report

The DPFU outputs a summary of the plotting and fitting process. The Summary Report contains the following information:

- NAMELIST parameters
- System-generated plot parameters such as plot scales
- Coefficients of the fit

7.3 SYSTEM STRUCTURE

The baseline diagram of the DPFU is given in Figure 7-5. The MAIN routine is the driver of the system. If multiple plots (i.e., parallel or serial stacked plots, overlays) are requested, the MAIN routine fully processes the first plot, then repeats the entire procedure for each of the remaining plots. Since each plot is produced from its own NAMELIST file, certain plot characteristics (such as axis labels) can be set individually.

The dataset input file is processed sequentially so that one point is plotted for each input record. If data-fitting is requested, the MAIN routine calls DFIT after each record is input to accumulate the sums needed to compute the least-squares fit. After all the data has been processed, MAIN calls SOLVE to calculate the coefficients for the fit, and then calls PLTCRV to plot the curve.

The DPFU uses several standard Calcomp utility subroutines that have been omitted from the system description for simplicity.

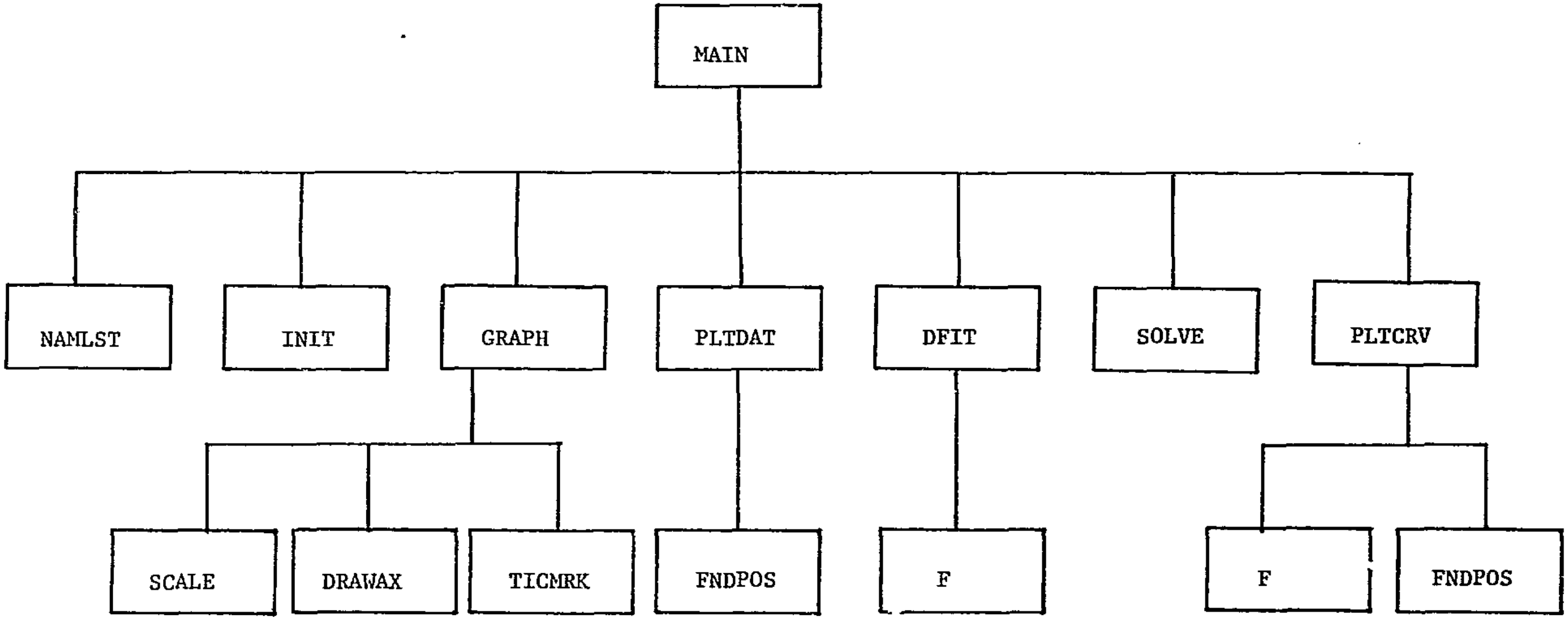


Figure 7-5 Data Plotting and Fitting Utility Baseline Diagram

7.4 SUBROUTINE DESCRIPTIONS

Each subroutine of the DPFU is described below.

MAIN

Purpose: MAIN serves as the driver of the DPFU.

Procedure:

(1) Call NAMLST to read in the plot parameters.

(2) Call INIT to set global parameters and set the origin.

(3) Call GRAPH to set scales, draw axes, and write labels.

(4) Read a data record.

(5) Call PLTDAT to plot the data.

(6) If IFIT = 1 or 2, call DFIT to accumulate sums.

(7) Repeat steps 4-6 for each data record.

(8) If IFIT = 1 or 2, call SOLVE to compute the coefficients for the least-squares fit.

(9) If IFIT = 1 or 3, call PLTCRV to plot the data-fitting curve.

(10) Repeat steps 1-9 for each plot.

Input Parameters: None

Output Parameters: None

NAMLST

Purpose: NAMLST reads the NAMELIST input file &DPFUIN.

Procedure:

(1) Perform NAMELIST read.

(2) Test for errors.

Input Parameters: None

Output Parameters:

IERR	Error flag:	
	IERR = 0	no error
	= 1	read error

The remaining output parameters are listed by common block:

/CTRL/

IOPT	Plot option flag
NPLOTS	Number of plots
IFIT	Data fitting option
ISIFT	Step size for data fitting procedure
XPOINT	Cut-off point on x-axis for series plot
IXVAR	x-variable selection
IYVAR	y-variable selection
ISCAN	Scanner number
MAXN	Maximum number of points to be plotted

/GRAPH/

ICHAR	Plot character
XLEN	x-axis length
YLEN	y-axis length
XMIN	Minimum x-value
XMAX	Maximum x-value
YMIN	Minimum y-value
YMAX	Maximum y-value
TSTEP	Time increment for x-axis tic marks

/LABELS/

TITLE	Graph title
XTITLE	x-axis title
YTITLE	y-axis title

/BASIS/

$$\left.\begin{array}{l}\text{ICONST}\\ \text{IDEG}\\ \text{ISIN}\\ \text{ICOS}\end{array}\right\}\text{ Basis function selection flags.}$$

INIT

Purpose: INIT initializes global parameters and determines the position of the plot origin.

Procedure:

(1) Initialize parameters.

(2) Set origin:

YO = YO + YMOVE

where YMOVE is based on YLEN. (XO is fixed for all plots)

Input Parameters:

YO	Current plot origin y-coordinate
YLEN	Length of y-axis

/BASIS/

ICONST IDEG ISIN ICOS	Selection flags for basis functions

Output Parameters:

HEIGHT	Height of plot in inches
WIDTH	Width of plot in inches

/DATFIT/

IMAP	Array mapping basis function selection flags to basis functions
NFIT	Order of the fit

GRAPH

Purpose: GRAPH sets up the "frame" of the current plot: it determines the scale, draws the axes, and writes labels.

Procedure:

(1) Call SCALE to determine plot scale.

(2) Call DRAWAX to draw the axes and tic marks.

(3) Call TICMRK to label the tic marks.

(4) Write plot title, axis labels.

Input Parameters:

XO,YO	Plot origin.
XMIN	Minimum x-value
XMAX	Maximum x-value
YIN	Minimum y-value
YMAX	Maximum y-value
XLEN	Length of x-axis in inches
YLEN	Length of y-axis in inches
TITLE	Graph title
XTITLE	x-axis label
YTITLE	y-axis label

Output Parameters:

SCALE	Scale factor
XINC	X-axis scale increment
YINC	Y-axis scale increment

SCALE

Purpose: SCALE computes the plot scale.

Procedure:

(1) Compute Scales:

XSCALE = WIDTH/(XMAX - XMIN)

YSCALE = HEIGHT/(YMAX - YMIN)

(2) Compute number and value of tic marks.

Input Parameters:

HEIGHT	Height of plot
WIDTH	Width of plot
XMIN	Minimum x-value
XMAX	Maximum x-value
YMIN	Minimum y-value
YMAX	Maximum y-value
XLEN	Length of x-axis in inches
YLEN	Length of y-axis in inches

Output Parameters:

XSCALE	X-axis scale factor
YSCALE	Y-axis scale factor
NXTIC	Number of tic marks for x-axis
NYTIC	Number of tic marks for y-axis
XTICS	Tic mark values for x-axis
YTICS	Tic mark values for y-axis
XDIST	Distance between tic marks on x-axis
YDIST	Distance between tic marks on y-axis

DRAWAX

Purpose: Draw the x and y axes and tic marks.

Procedure:

(1) Draw x-axis
(2) Place tic marks on x-axis
(3) Draw y-axis
(4) Place tic marks on y-axis

Input Parameters:

XO, YO	Plot origin
XLEN	Length of x-axis in inches
YLEN	Length of y-axis in inches
NXTIC	Number of tic marks on x-axis
NYTIC	Number of tic marks on y-axis
XDIST	Distance between tic marks on x-axis
YDIST	Distance between tic marks on y-axis

Output Parameters: None

TICMRK

Purpose: TICMRK labels the tic marks on the x and y axes.

Procedure:

For each axis, perform the following:

(1) Based on spacing, determine which tic marks should be labeled.

(2) Use XTICS, YTICS to label the selected tic marks.

Input Parameters:

XO, YO	Plot origin
NXTICS	Number of x-axis tic marks
NYTICS	Number of y-axis tic marks
XDIST	Distance between tic marks on x-axis
YDIST	Distance between tic marks on y-axis
XTICS	Tic mark values on x-axis
YTICS	Tic mark values on y-axis

Output Parameters: None

PLTDAT

Purpose: PLTDAT plots a single data point.

Procedure:

(1) Call FNDPOS to determine plot coordinates corresponding to the data point.

(2) If ICHAR=blank, leave pen down and move to new data point.

(3) If ICHAR≠blank, raise pen, move to new data point, draw plot character ICHAR.

Input Parameters:

XDAT	X-value
YDAT	Y-value
XSCALE	X-axis scale factor
YSCALE	Y-axis scale factor
HEIGHT	Plot height
WIDTH	Plot width
ICHAR	Plot character

Output Parameters:

NONE

FNDPOS

Purpose: FNDPOS computes the x and y coordinates of a given data point.

Procedure:

(1) Compute X-coordinate
(2) Compute Y-coordinate

Input Parameters:

XMIN	X-axis minimum value
XMAX	X-axis maximum value
YMIN	Y-axis minimum value
YMAX	Y-axis maximum value
XSCALE	X-axis scale factor
YSCALE	Y-axis scale factor
XDAT	X-value
YDAT	Y-value

Output Parameters:

X	X-coordinate
Y	Y-coordinate

DFIT

Purpose: DFIT accumulates the sums needed for the least-squares fit using the selected data points.

Procedure:

(1) Accumulate right-hand side vector:

```
B(K) = B(K) + F(K,X)*Y FOR K=1, NFIT
```

(2) Accumulate least-squares matrix:

```
A(J,K) = A(J,K) + F(J,X) * F(K,X)
for J=1, NFIT; K=1, NFIT
```

Input Parameters:

NFIT	Order of the fit
X	X-value
Y	Y-value

Output Parameters:

B	Right hand side of least squares system
A	Least-square matrix

F

Purpose: F is a function that evaluates a selected basis function at a given point X.

Procedure:

(1) Determine which basis function to evaluate based on input parameter IBASIS.

(2) Evaluate the selected function.

Input Parameters:

IBASIS	Index indicating which basis function is to be evaluated.
X	Point to be evaluated.

The remaining input parameters are from common block /DATFIT/:

IMAP	Array mapping IBASIS index to selected basis function.
NFIT	Order of the fit.

Output Parameters:

F	Function value at point X.

SOLVE

Purpose: SOLVE computes the solution of the linear system of equations, AX = B.

Procedure:

(1) Compute the LU decomposition of the matrix A using the Cholesky decomposition method.

(2) Back-solve to compute X.

Input Parameters:

A	Matrix of coefficients
B	Right hand side
N	Order of the system
NDIM	Actual row dimension of A

Output Parameters:

X	Solution vector
IERR	Error flag: IERR = 0 no error = 1 A is singular

PLTCRV

Purpose: PLTCRV plots the data-fitting curve.

Procedure:

(1) Evaluate least-squares fit at selected point.
(2) Call FNDPOS to obtain X and Y coordinates of the data point.
(3) Move pen to computed position.
(4) Repeat (1)-(3) for each selected point.

Input Parameters:

C	Array of computed least-squares coefficients
XMIN	Minimum X-value
XMAX	Maximum X-value
YMIN	Minimum Y-value
YMAX	Maximum Y-value
XSCALE	X-axis scale factor
YSCALE	Y-axis scale factor
XINC	Step size for curve

Output Parameters:

NONE

SECTION 8 - SCAN PATH PLOTTER

8.1 FUNCTIONAL DESCRIPTION

The scan path plotter draws the ground path of a scanner field-of-view on a perspective view of the Earth grid. This is used to show the positions on the Earth viewed by the scanner. The Earth grids generated by this utility can be overlaid on GOES infrared photographs to show the meteorological conditions viewed by the scanner.

The following steps are performed in the computation of the scanner ground track.

Step 1

The perspective view of a spherical latitude-longitude grid is drawn, and parameters are initialized for the drawing of general curves on this grid.

Step 2

The input attitude and spacecraft position information are used to compute the scanner spin axis vector and expected Earth width.

Step 3

For each scanner rotation angle in the sweep across the Earth, the latitude and longitude of intersection of the scanner line-of-sight with the Earth is computed and stored in an array. This intersection is computed for very small steps in the scanner rotation angle near the horizons, where the surface intersection position changes rapidly, and for larger steps in the scanner rotation angle near the middle of the scan.

Step 4

The curve described by the arrays of latitude and longitude intersection points is plotted on the Earth grid.

Step 5

Steps 3 and 4 are repeated for a second scan cone angle. The two scan cone angles are usually selected to bracket the sensor field-of-view.

Step 6

Lines are drawn connecting the scan cones at selected positions. These positions may be specified by the following:

- o Degrees of rotation angle from the Earth center direction
- o Degrees of rotation angle after the Earth-in crossing (specifically the average of the Earth-in crossings for the two cones)
- o Degrees of rotation angle before the Earth-out crossing (specifically, the average of the Earth-out crossings for the two cones)

Step 7

The subsatellite position is marked on the Earth Grid.

Step 8

Steps 2 through 7 are repeated for additional scan path plots.

8.2 INPUTS AND OUTPUTS

8.2.1 NAMELIST Inputs

The scan path plot generation is controlled through two different NAMELISTS which are read from the same input file. The first NAMELIST which is read, &EARTHG, defines the sphere grid upon which the scan paths are to be plotted. The next NAMELIST which is read, &IRSCAN, defines the parameters for drawing the ground track of a pair of scan cones which bracket the sensor field-of-view. As many of the &IRSCAN NAMELISTS as desired may be stacked in the NAMELIST input dataset so that several scan paths may be drawn on one Earth grid. A control parameter in the &IRSCAN NAMELIST indicates whether a new Earth Grid should be drawn.

These two NAMELISTS are described in the following pages.

&EARTHG NAMELIST:

ALFO	East longitude of the center of the view of the Earth grid, from 0 to 360 degrees (West longitudes can be converted to East lonitude by subtracting from 360).
DELO	Latitude of the center of the view of the Earth grid, from -90 to 90 degrees (South latitudes are given by negative values).
RADIUS	Radius of Earth grid drawing in inches.
RVIEW	Distance at which the Earth grid is viewed in kilometers for perspective effects.
RERTHG	Radius of Earth grid in kilometers for the computation of perspective effects (Default value is 6378.14).
INTVL	Interval of latitude and longitude lines on the Earth grid in degrees.
ITVPOL	Interval of longitude lines near the poles in degrees.
LATPOL	North and South latitude past which ITVPOL applies.

&IRSCAN NAMELIST

Main Control Parameters

ISCAN Scan Drawing Option
= 0, Do not draw scan path
= 1, Draw pair of scan paths

ISUB Subsatellite point marking option
= 0, Do not mark the subsatellite point
= 1, Draw mark to indicate the subsatellite point

NEWGRD New Earth grid selection option.
= 0, Do not draw a new Earth Grid. The next &IRSCAN NAMELIST which is read from the input dataset will define a new scan path to be drawn on the same grid.
= 1, Draw a new Earth grid. The next &EARTHG NAMELIST which is read from the input dataset will define a new grid to be plotted.

Scan Cone Parameters

SCONE(2) Pair of scan cone angles for which ground paths will be drawn (these are usually chosen to bracket the sensor field-of-view)

IMARKS(200) Indicator for positions on the scan path which are to be marked by lines between the two scan cone paths.
= 0, No mark
= 1, Draw mark at SMARKS(I) degrees of scan rotation angle from the middle of the Earth width.

= 2, Draw mark at SMARKS(I) degrees after the Earth-in crossing direction.

= 3, Draw mark at SMARKS(I) degrees before the Earth-out crossing.

SMARKS(200) Scan rotations for marks as defined by the variable IMARKS.

Scan Axis Definition Parameters

IATT Indicator of the source of the scan axis attitude

= 0, Input the scan axis right ascension and declination, using the NAMELIST parameters RAAXI and DECAXI

= 1, Specify the scan axis by its azimuth relative to the flight path and its elevation relative to the local horizontal plane, using the NAMELIST parameters AZAXI and ELAXI.

= 2, Input the spacecraft pitch, roll, yaw attitude and the scanner mounting alignment angles, using the NAMELIST parameters PITCH, ROLL, YAW, AZI, TILT.

Note: For IATT = 1 or 2 the orbit parameters EYE and RANODE are used to determine the flight direction so that these orientations relative to the orbit frame are defined in GCI coordinates.

RAAXI Right ascension of the scan axis in degrees

DECAXI Declination of the scan axis in degrees

AZAXI Azimuth angle of the scan axis, defined as a right hand rotation about the nadir vector from the flight direction to the scan axis in degrees

ELAXI	Elevation of the scan axis above or below the local horizontal plane, in degrees
PITCH	Spacecraft pitch attitude
ROLL	Spacecraft roll attitude
YAW	Spacecraft yaw attitude
AZI	Scanner azimuth alignment
TILT	Scanner tilt alignment

Spacecraft Position Parameters

IPOS	Indicator of the source of the spacecraft position relative to the Earth grid. = 0, Input the spacecraft right ascension and declination distance from the geocenter, and GMT time, using the NAMELIST parameters RASAT, DECSAT, DISTE, and TIME. = 1, Input the spacecraft subsatellite latitude and longitude and altitude above the surface, using the NAMELIST parameters SATLAT, SATLON, SATALT. = 2, Input the TIME and spacecraft orbital elements, using the NAMELIST parameters TIME, A, E, EYE, WO, RANODE, EMO, and EPOCH.
TIME	Time in format YYMMDD.HHMMSS
RASAT	Spacecraft right ascension position
DECSAT	Spacecraft declination position
DISTE	Distance from the spacecraft to the Earth center
SATLAT	Subsatellite latitude
SATLON	Subsatellite longitude
SATALT	Satellite altitude above the surface
EPOCH	Epoch time for orbital elements in format YYMMDD.HHMMSS

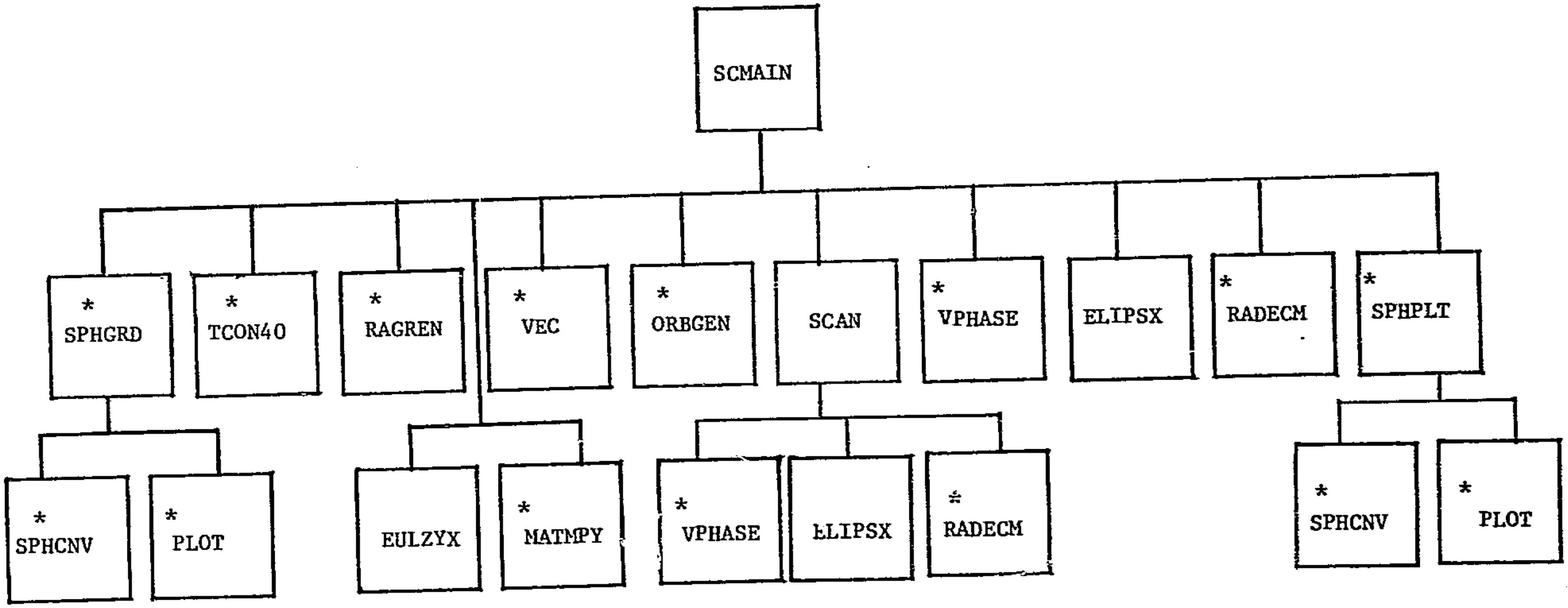
A	Orbit semi-major axis (km)
E	Orbit eccentricity
EYE	Orbit inclination
WO	Orbit argument of perigee
RANODE	Orbit right ascension of ascending node
EMO	Orbit mean anomoly

Earth Parameters

REARTH	Radius of the Earth in kilometers
FLATC	Earth oblateness coefficient

8.3 SYSTEM STRUCTURE

Figure 8-1 shows the baseline diagram for the Scan Path Plotter. SCMAIN serves as the driver for the system. It reads the input NAMELISTS and controls the program flow. Figure 8-2 shows the data flow.



* Existing Software Available in Standard Utility Package.

Figure 8-1 Scan Path Plotter Baseline Diagram

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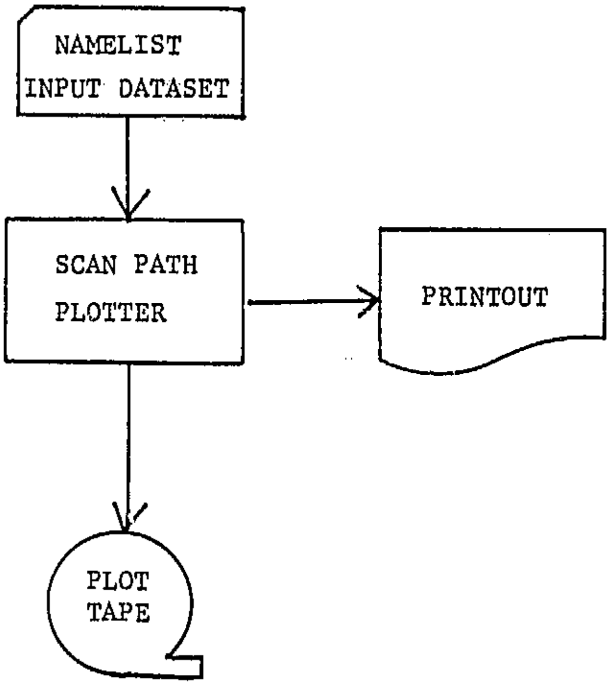

Figure 8-2 Scan Path Plotter Flow Diagram

8.4 SUBROUTINE DESCRIPTIONS

The purpose, procedure, inputs, and outputs of the scan path plotter subroutines are described as follows:

SCMAIN

Purpose: SCMAIN serves as the driver of the scan path plotter.

Procedures:

(1) Read and write NAMELIST input dataset card images.
(2) Read the NAMELIST &EARTHG and call SPHGRD to draw the Earth grid.
(3) Read the NAMELIST &IRSCAN.
(4) Call TCON40 and RAGREN to compute the right ascension of Greenwich, England.
(5) Get the satellite position vector in GCI coordinates by calling VEC, or ORBGEN according to the spacecraft position input option IPOS.
(6) Get the scan axis vector in GCI coordinates by calling EULZYX, MATMPY, or VEC according to the scan axis attitude input option IATT.
(7) Call SCAN to step the scan across the Earth and compute the ground track of the scanner.
(8) Call SPHPLT to draw the scan cone on the Earth grid.
(9) Mark the specified positions on the scan cone.
(10) If required, plot the subsatellite point marker.
(11) If NEWGRD = 0, return to step 3
If NEWGRD = 1, return to step 4

Stop when an end-of-file is reached on the NAMELIST input dataset.

Input Parameters: None

Output Parameters: None

SCAN

Purpose: To compute the Earth in crossing, Earth out crossing and ground track of a scan across the Earth.

Procedure:

(1) Get an estimate for the Earth width, using the spherical Earth equation.

(2) Choose a scan rotation angle just before the horizon entry position.

(3) Determine the scanner line-of-sight vector for this scan rotation angle by calling VPHASE.

(4) Determine if the line of sight vector intersects the Earth and, if it does, determine the position of the nearest intersection point, by calling ELIPSX.

(5) Call RADECM to obtain the latitude and longitude of the Earth intersection points and store in the output arrays. To keep the array usage down, do not store points within a fixed proximity to previous points.

(6) Increment the scan rotation angle and return to step (3) until the line-of-sight leaves the Earth. This increment is very small near the horizon crossings and larger near the middle of the scan.

(7) Call RADECM to obtain the latitude and longitude of the last Earth intersection point and store in the output arrays.

Input Parameters:

VSCANR	Scan axis unit vector
GAMMA	Scan cone radius
REARTH	Earth equatorial radius

FLATC	Earth oblateness coefficient
VERSAT	Earth to satellite position vector in kilometers
ILEVEL	Debug printout level

Output Parameters:

PHIIN	Earth in rotation angle
PHIOUT	Earth out rotation angle
SCNLAT(N)	Array of latitudes of the ground track
SCNLON(N)	Array of longitudes of the ground track
N	Number of points in ground track arrays

ELIPSX

Purpose: To determine if a particular line of sight intersects an Earth ellipsoid, and if it does, to provide the position vector of the first intersection point.

Procedure: The formulas for this evaluation are discussed in Reference 4, section 3.6.1.

(1) Determine if the line of sight intersects the ellipsoid. If not, return flag values.
(2) Determine the distance to the nearest point of intersection.
(3) If this distance is negative, the line-of-sight points away from the Earth or the viewer is inside the Earth and flag values are returned.
(4) Use the distance to the nearest point to obtain the position vector of the intersection.

Input Parameters:

VFOV	Line of sight unit vector
VERSAT	Vector from the Earth to the satellite
REARTH	Earth equatorial radius
FLATC	Earth flattening coefficient

Output Parameters:

VHIT(3)	Position vector of ellipse intersection in kilometers
IERR	Error indicator
	= 0, No error
	= 1, line does not hit Earth
	= 2, viewer inside Earth
	= 3, viewer looking away from Earth
	(If IERR .NE. 0, VHIT is set to $(2.0, 2.0, 2.0)^T$)

EULZYX

Purpose: To compute the rotation matrix that corresponds to a 3-2-1 Euler rotation sequence.

Procedure:

$$\{T\} = \begin{bmatrix} cYcX & cYsX & -sY \\ -cZsX+sZsYcX & cZcX+sZsYsX & sZcY \\ sZsX+cZsYcX & -cZcX+cZsYsX & cZcY \end{bmatrix}$$

where the abbreviations s = sine and c = cosine are used.

Input Parameters:

Z	First Euler rotation angle in degrees
Y	Second Euler rotation angle in degrees
X	Third Euler rotation angle in degrees

Output Parameters:

T(3,3) Rotation matrix

REFERENCES

1. LANDSAT-D Conical Scanner Evaluation Plan, Stephen Bilanow, Lily Chen, General Software Corporation GSC-TR8203, March 1982.

2. Horizon Radiance Data Base Format (Revised), S.P. Singhal, Computer Science Corporation B61-I-42604-09, Feb. 4, 1982.

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5. The Horizon Radiance Modeling Utility System Description and User's Guide (Premiminary Draft), Dr. W. Nutt, Computer Sciences Corporation CSC/SD-78/6032, March 6, 1978.